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MERCURY, ZINC, COPPER, ARSENIC, SELENIUM, AND CYANIDE CONTENT OF SELECTED WATERS AND SEDIMENT COLLECTED ALONG WHITEWOOD CREEK, THE BELLE FOURCHE RIVER, AND THE CHEYENNE RIVER IN WESTERN SOUTH DAKOTA. DECEMBER 1971-OCTOBER 1972

Environmental Protection Agency
Denver, Colorado

April 1973

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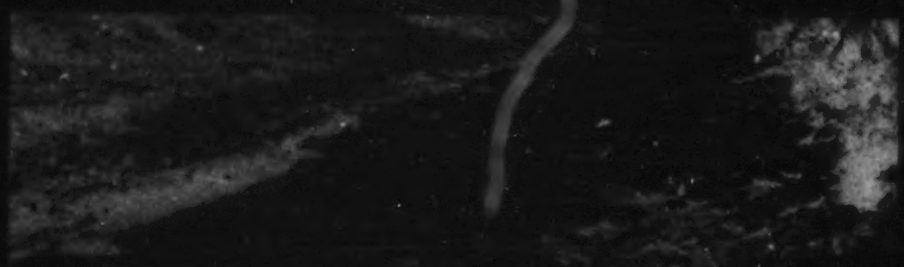

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TECHNICAL SUPPORT BRANCH

SURVEILLANCE AND ANALYSIS DIVISION

ENVIRONMENTAL PROTECTION AGENCY

REGION VIII

DENVER, COLORADO

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16. Abstracts Alluvial sediments resembling tailings material derived from mining operations in the northern Black Hills of South Dakota were identified as covering an excess of 1100 hectares of land paralleling White Wood Creek and the Belle Fourche River downstream of Lead, S Dakota, in 1971-72. Assay of 40 samples of this material indicated that the material contained, on the average, < 0.6 ppm of mercury, 81 ppm of zinc, 63 ppm of copper, and 30-50 ppm of arsenic. With the exception of zinc, these concentrations were higher than average "background" concentrations. Also assayed were 60 samples of shallow ground water collected from near the banks of Whitewood Creek & the Belle Fourche River. The mercury, zinc, copper, arsenic, & cyanide were not in excess of the limits set up. However, selenium concentrations were above average in samples taken from wells along the Cheyenne River.

17. Key Words and Document Analysis. 17a. Descriptors

Alluvium
* Mercury
* Zinc
* Copper
* Arsenic
* Selenium
* Cyanide
* Water pollution

17b. Identifiers/Open-Ended Terms

* Whitewood Creek
* Belle Fourche River
* Cheyenne River

17c. COSATI Field/Group

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December 1971 - October 1972

A Report Submitted to the Conferees of the
Conference in the Matter of Pollution of the
Navigable Waters of Western South Dakota

TECHNICAL SUPPORT BRANCH
SURVEILLANCE AND ANALYSIS DIVISION
U. S. ENVIRONMENTAL PROTECTION AGENCY
REGION VIII

April 1973

ABSTRACT

Alluvial sediments resembling tailings material derived from mining operations in the northern Black Hills of South Dakota were identified as covering in excess of 1100 hectares of land paralleling Whitewood Creek and the Belle Fourche River downstream of Lead, South Dakota, in 1971-72. Assay of 40 samples of this material indicated that the material contained, on the average, $\leq$ 0.6 ppm of mercury, 81 ppm of zinc, 63 ppm of copper, and 2050 ppm of arsenic. With the exception of zinc, these average concentrations were higher than average "background" concentrations. Also assayed were 68 samples of shallow ground water collected from near the banks of Whitewood Creek and the Belle Fourche River. The results of chemical assay indicated that concentrations of mercury, zinc, copper, arsenic, and cyanide in these waters were not in excess of the limits placed upon waters used for domestic and agricultural purposes. However, the results of assay of samples from these wells and wells located along the Cheyenne River near Wasta, South Dakota, did indicate that selenium concentrations in excess of 0.020 mg/l were present in certain wells in the lower Cheyenne River Basin. The recommended limit concentration for selenium in drinking water is currently 0.010 mg/l.

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INTRODUCTION

This report presents physical and chemical data describing the river alluvium and shallow ground water extant in the Cheyenne-Belle Fourche-Whitewood Creek drainage system of southwestern South Dakota, downstream of Lead, South Dakota. The collection and assay of samples were accomplished over the period December 1971 through December 1972 by the Region VIII staff of EPA, assisted by the National Division of Field Investigations and the South Dakota Department of Health (Division of Sanitary Engineering and Environmental Protection).

This effort was requested in October of 1971 in the form of two "Recommendations" contained in the "Proceedings"[1] of the Conference convened in Rapid City to address the pollution affecting the Cheyenne River System. These two recommendations were:

1. "6. The location and composition of buried tailings materials, including abandoned tailings piles, along Whitewood Creek, the Belle Fourche River, and the Cheyenne River shall be ascertained and documented and the rates of release of heavy metals and toxic elements to be established by the State of South Dakota and the Environmental Protection Agency by October 1, 1972, and findings reported to the Chairman and the conferees. South Dakota will provide the Chairman of this group.

2. "7. Arsenic concentrations in wells in the Cheyenne Basin shall be determined and documented by the State of South Dakota and the Environmental Protection Agency to ascertain whether these sources are acceptable for domestic or agricultural water supply uses and the findings shall be reported to the Chairman and the conferees within six months of the date of this conference. EPA will provide technical services."

Most of the information relating to pollution of that portion of the Cheyenne River Basin under discussion was provided by EPA prior to the Conference of October 1971, in a report[2] prepared by the EPA National Field Investigations group in Denver. Two conclusions reached by that group are pertinent and are therefore listed below:

1. "6. Previously-discharged Homestake tailings solids have been deposited along Whitewood Creek and the Belle Fourche and Cheyenne Rivers. These solids are eroded and leached during high stream flows. Buried deposits of tailings solids occur in abandoned river meanders, chiefly along the Belle Fourche River.

---

1) Conference Proceedings in the Matter of Pollution of the Navigable Water of Western South Dakota - USEPA (1971).
2) "Report on Pollution Affecting Water Quality of the Cheyenne River System, Western South Dakota" - September 1971.

Leaching of mercury from such deposits contaminates ground water, as well as surface streams. The ground water is used as a supply for domestic wells. Large quantities of mercury are contained in the buried tailings and may be leached by ground water. After cessation of the discharge of solids from Homestake, the deposits will be eroded by surface streams as the streams adjust to a new hydrologic regime. Research is currently underway to develop methods of recovering mercury from sediments. The buried tailings also contain large quantities of arsenopyrite which may be leached to surface streams or ground water."

2. "4. Analyses of effluents discharged during June 1971 showed the Homestake Mining Company to be adding daily loads of 312 pounds (142 kg) of cyanide, 240 pounds (10^9 kg) of zinc, 72 pounds (33 kg) of copper, and 2735 tons (2.5×10^6 kg) of suspended solids to Whitewood Creek. The tailings solids include a load of 9.5 tons (0.086×10^6 kg) per day of arsenic in the form of arsenopyrite, an arsenic-iron sulfide. The arsenopyrite is oxidized, resulting in arsenic concentrations in the Cheyenne River which are four times greater than the U. S. Public Health Service water supply criterion."

The effort presented in this report was directed toward (1) locating and determining the chemical composition, in terms of mercury (Hg), zinc (Zn), copper (Cu), and arsenic (As), of sediments along the Whitewood Creek-Belle Fourche-Cheyenne River system which appeared to be similar to tailings materials, and (2) sampling and determining the chemical composition, in terms of selected metals and cyanide, of shallow ground water used by inhabitants of lowland areas in the vicinity of the surface drainage system affected by discharges from the Homestake operations.

RESULTS OF ANALYSES OF SEDIMENT AND SHALLOW GROUND WATER

Sediment Samples

Forty-eight one-pint samples of sediment and seven sediment cores were collected from the survey area during the period July 17-21, 1972. Samples were collected with shovels and with a hand-driven, thin-wall corer. Sample locations were based upon the results of the interpretation of multi-spectral imagery obtained from aircraft flown over the area in 1971. The interpretation was provided by the EPA National Field Investigations group in Denver[3]. The graphical results of this tailings-identification effort are provided in the rear of this report (Figures 2 thru 22) and sample locations are also denoted in these figures and in Figure 1.

In general, the field investigations of sediment occurrence conducted in July of 1972 showed the limits of tailings deposits, as derived from the photographic mission conducted on November 20 and 23, 1971, to be accurate. It had been estimated[3] that the area affected by the tailings equalled about 1100 hectares[5]-(80 hectares on Whitewood Creek and 1000 hectares on the Belle-Fourche River). In the opinion of the author of this report, the dark tailings material, considered characteristic of the present Homestake discharge, was spread over a somewhat greater area in July of 1972 than was shown in the November 1971 photography, but this additional material was not generally found in any appreciable thicknesses. The difference is attributed, primarily, to the occurrence of higher flows in the period elapsing between photography and sampling. Grayish-colored "tailings" were not generally found to any substantial depth. The thickest deposits encountered in 1972 (1.7 m.) were limited to isolated near-shore or bank deposits. However, substantial amounts and thicknesses of red-brown sand were encountered in Whitewood Creek and downstream of Whitewood Creek on the Belle Fourche River. These red-brown sands appeared to be associated with past discharges of tailings material into Whitewood Creek. Except where hidden by vegetation or thin gravel cover, the position of these reddish sands were coincident with the locations selected from the photography.

Sediment sites and sampling data are discussed and presented in Table 1. Descriptions of the samples and cores are included. The results of chemical assay for mercury, zinc, copper, and arsenic are presented in Table 2. Selenium data are not yet available. Background data, that is, "background" in relationship to the present discharge from the Homestake operation, were collected at Sites BF-1, BF-2, C-1, and CT-1.

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3) "Report on Remote Sensing Study, Whitewood Creek/Belle Fourche River, South Dakota, Jan. '72".
4) Color photographs are provided in a limited number of copies of the report (Appendix III).
5) Hectare = 10^4 square meters = square hectometer.

TABLE 1

Description of Sediment Sampling Sites and Samples Collected Along Whitewood Creek, Belle Fourche and Cheyenne Rivers, South Dakota (17-21 July 1972) (followed by Core Log).

WHITEWOOD CREEK

Site WC-1

T6N; R3E; NE, NE, 33 Deadwood North Quad.

1. Samples collected: SD-SED-4 (pint sample)- 18 Jul 72 - #10957

2. Location: North bank of Whitewood Creek, 15m. upstream of bridge, 150m. southeast of Johnson Residence, about 2.1 km SSE of Town of Whitewood, S.D., and about 14.5 km NE of Lead, S.D., at "Crook City." Bridge is for small dirt road. Lawrence County.

3. Occurrence of "Tailings": Tailings - like material, a fine gray sandy silt occurs to a depth of 15 cm or so along the concave sides* of the Creek. This silt overlies gravel and sand. Similar deposits occur in a spotty fashion along all of the channel visible from this location. They are seldom wider than 1 meter.

4. Further description of material sampled: Sample contains red-brown mica.

5. Relationship to Photo-interpretation: Between Areas 1 and 2. Site WC-1 not identified as one with tailings in 1971 photography, perhaps due to the thinness of the deposits and the eight-month period elapsing between the photography and sampling.

* Similar to "point bar deposits".

Site WC-2

T6N; R4E; NW 22 Sturgis Quad.

1. Samples collected: SD-SED-5A; SD-SED-5B (both pint samples); SD-SED-5C and 5C "duplicate" (core sample). 18 Jul 72 - #10952; #10948.

2. Location: East bank of Whitewood Creek, 10m. upstream of bridge. 1.6km. northeast of Whitewood, South Dakota at Whitewood Valley Road across Whitewood Creek; Lawrence Co.

3. Occurrence of "Tailings": Tailings - like material, a somewhat coarse gray sandy silt with some brown sand occurs along a relatively wide deposit (up to 12 meters) deposited along the convex side of the Creek. The silt consists of from a thin crust up to about 30 cm. overlying alluvial sand and gravel. At depths from 8 cm. or more a relatively fine, gray-brown sand was encountered with only minor silt present.

4. Further description of material sampled: Sample contains mica as small (a few millimeters) flecks. Sample SD-SED-5A collected from upper 15 cm. consisting of gray-brown silt and sand. Sample SD-SED-5B collected from lower 15 cm. consisting of gray-gray-brown to red sand. These samples collected from middle of deposit. Sample SD-SED-5C is a core collected from the deposit near the flowing Creek.

   Core description: See core log.

5. Relationship to Photo-interpretation: Southern end of Area 4. Field inspection indicates that delineations derived from photography are accurate in this area. New tailings deposit caused by ice jam along flat area west of Creek and upstream of bridge.

Site WC-3

T6N; R4E; NE, NW 15-SE, SW 10 Sturgis Quad.

1. Samples Collected: SD-SED-14A through 14F (6 samples, pint samples); 20 Jul 72.

2. Location: East bank of Whitewood Creek, about 2.0 km. downstream from Site WC-2. Collections made 10 to 50 meters west of Whitewood Valley Road; Lawrence County.

3. Occurrence of "Tailings": Tailings - like material, a dark gray silt with minor sand, was found as a 10 cm. covering over gravel deposits at two levels, one recent and paralleling the Creek and another, older layer located somewhat away from the stream and 60 cm. above the recent silt. The silt was randomly distributed over the area and the layer identified as "recent" did not extend under the higher layer. Fresh material was found along the convex side of the Creek while the older material covered an abandoned deposit connected to a convex portion of the Creek. Buried "tailings" were found beneath silt and sand along low areas of an extensive channel deposit upstream of the fresher silt.

TABLE 1 (Cont.)

Site WC-3 (Cont.)

4. Further description of material sampled:

SD-SED-14A - Black, highly organic (?) material from established (feed) stream bank. Collected for the purpose of verifying that these older black beds, approximately 7 cm. thick; are not tailings material. (#10983)

SD-SED-14B - Fresh, lower silt covering gravel bar in channel of Whitewood Creek, approximately 10 cm. deep. (#10982)

SD-SED-14C - Older silt on bar, 60 cm. above and upstream of 14B; not analyzed.

SD-SED-14D - Yellow, green (Iron rich?) silt and sand from low area on terrace. Red shale at 10 cm. (#10988)

SD-SED-14E - Gray silt and clay from 5 cm. thick layer located approximately 25 cm. beneath surface in low area on terrace. 1.5 m. above Creek, over slight rise, about 10 m. east of Creek. (#10987)

SD-SED-14F - Red, brown sand from beneath (TD 45 cm.) silt layer of 14E; mixed with pebbles. (#10986)

5. Relationship to Photo-Interpretation: No photography

Site WC-4 T6N; R4E; C, N 1/2, NW, 2 St. Onge, SE Quad.

1. Samples Collected: SD-SED-15 (pint sample)- 20 Jul 72 - #10985

2. Location: West bank of Whitewood Creek, 5 m. upstream of bridge, 1.4 km. north of Hathaway School (Saint Onge SE. 1954); Lawrence County.

3. Occurrence of "Tailings": Tailings - like material, a dark gray to black silt, occurs as a 15 cm.± thick covering over alluvial gravel and sand. Deposit is about 7 m. wide at sample site and narrows in a fashion typical of alluvial deposits.

4. Further description of material sampled: Material was wet, and relatively fresh.

5. Relationship to Photo-interpretation: At northeast extremity of Area 14.

Site WC-5 T7N; R4E; C, S 1/2, NE, 25 St. Onge, SE Quad.

1. Samples Collected: SD-SED-6A; SD-SED-6B (pint samples); 18 Jul 72 - #10950

2. Location: South bank of Whitewood Creek, 75 to 100 m. upstream of bridge (Whitewood Valley Road), 0.4 km. west of Lawrence - Meade County Line; Lawrence County.

3. Occurrence of "Tailings": Tailings - like material occurs as thin (3+cm.) surface covering over alluvial sand and gravel. #6B was collected from this covering in an abandoned (recently) channel. #6A was collected from a 7 cm.-thick silty clay layer occurring about 0.5 m. deep in an old bar (vegetation on top) dividing the current channel from the abandoned channel of sample #6B.

4. Further description of material sampled: #6A - fine, dark gray silt, minor sand. #6B - fine, dark gray sand, mid-silt, overlying red-brown sand and gravel.

5. Relationship to Photo-interpretation: Between Areas 21 and 22. Bar deposit (SD-SED-6A) too deep for detection. Channel deposit (SD-SED-6B) probably Spring-time deposit occurring post-photography. Inspection of east portion of Area 21 indicated no appreciable concentrations of tailings - type material (north bank of Creek).

Site WC-6 T7N; R5E; SE, SW, 4 St. Onge, SE Quad.

1. Samples Collected: SD-SED-7 (pint sample); 18 Jul 72 - #10953

2. Location: East bank of Whitewood Creek, 15 m. downstream of bridge; Meade County.

3. Occurrence of "Tailings": Tailings - like material covers alluvial gravel and sand as a thin (few centimeters thick) surface layer.

4. Further description of material sampled: Fine, dark gray sand, silt, minor clay.

Site WC-6 (Cont.)

5. Relationship to Photo-interpretation: Between Areas 34 and 35 but included on P. I. as thin band.

Site WC-7 T8N; R5E; C, S 1/2, SE, 26. Vale Quad.

1. Samples Collected: SD-SED-8A through 8D (core); 18 Jul 72.
2. Location: Northwest bank of Whitewood Creek, about 30 m. upstream of bridge, about 5.6 km. west of Vale, S. D. - Butte County.
3. Occurrence of "Tailings": Tailings - like material occurs as an isolated thick (approximately 1.1m.) bank deposit and as thin coverings of alluvial gravel and sand.
4. Further description of material sampled: See core log.
5. Relationship to Photo-interpretation: In Areas 41 and 42.

BELLE FOURCHE RIVER

Site BF-1 T8N; R5E; SE, NE, 7

1. Samples Collected: SD-SED-16A, SD-SED-16B (pint samples); 20 Jul 72 - #10992; #10991
2. Location: North bank of Belle Fourche River, 3 m. downstream of bridge and 1 m. north of River (#16A) and 25 m. upstream of bridge, 4 m. north of River (#16B), 0.8 km. south of Nisland, S. D., upstream of Whitewood Creek - Butte County.
3. Occurrence of "Tailings": No material similar in color to tailings. Silty clay covers gravel and lies as bank deposit along channel.
4. Further description of material sampled: #16A - Surface silt and sand. Primarily gray-brown silt with brown and white (qtz) sand. #16B - Gray clay, silt, with minor quartz sand and red-brown sand.
5. Relationship to Photo-Interpretation: No photography.

Site BF-2 T8N; R5E; SE, NE, 10 Newell Quad.

1. Samples Collected: SD-SED-17 (pint sample); 20 Jul 72 - #10990
2. Location: South bank of Belle Fourche River, 15 m. downstream of bridge, 5 m. south of River, 4.8 km. west of Nisland, 0.8 km. south of highway U. S. 212, upstream of Whitewood Creek, Butte County.
3. Occurrence of "Tailings": No material exactly similar to tailings. Silty clay covers gravel and lies as bank deposits along channel.
4. Further description of material sampled: Dark gray silt, clay, with minor organic material.
5. Relationship to Photo-Interpretation: No photography.

Site BF-3 T8N; R6E; SW, SW, 20 Newell Quad.

1. Samples Collected: SD-SED-9A through 9C (cores in pint samples); 18 Jul 72 - A #10949; B #10951; C #10947.
2. Location: North bank of Belle Fourche River, 35 m. downstream of S. D. highway 79 bridge, #9A 1 m. north of River, #9B, #9C 13 m. north of River; about 2.7 km. northwest of Vale, S. D., near stock well (water sample site #7). (Butte County)
3. Occurrence of "Tailings": Tailings - like material found as thin (6 to 12 cm.) covering over alluvial sand and gravel from River north some 15 m. onto bank. Short cores were collected of "tailings" material and of sand underlying the silt.
4. Further description of material sampled: #9A - dark gray silt, clay, with minor sand, small pebbles from 7.6 cm. long core of surface material; #9B - dark gray and brown

TABLE 1 (Cont.)

Site BF-3 (Cont.)

silt, brown sand, from 12.5 cm.-long core of surface material; #9C - brown-red sand from lower 20 cm. of 46 cm. deep core hole beneath sample #9B.

5. Relationship to Photo-Interpretation: In west end of Area 6; visual observations of tailings agree well with P. I.

Site BF-4 T8N; R6E; SE, NE, 28 Newell Quad.

1. Samples Collected: SD-SED-10 (Core); 18 Jul 72.
2. Location: Northwest bank of Belle Fourche River, about 20 m. upstream of bridge, 1.7 km. northeast of Vale. Sample collected from relatively thick bank deposit. Also, general location of sediment Transect #1 (p. 82, EPA Report "Pollution Affecting Water Quality of the Cheyenne River System, Western South Dakota," Sep. 71.)- Butte Co.
3. Occurrence of "Tailings": Tailings-like material found as relatively thick bank deposit covering small area upstream of bridge. Material is windblown and apparent thickness of 1 m. is caused by sloughing of material into channel. About 30 cm. of gray silt were encountered on top of the bank. The silt also contains brownish-red sandy material thought to differ from tailings. Core bottomed in sandy gravel at total depth of 46 cm.
4. Further description of material sampled: 30 cm. core from top of 46 cm. hole. See core log.
5. Relationship to Photo-Interpretation: In middle of area 11A.

Site BF-5 T8N; R7E; SE, NW, 27 Vale NE Quad.

1. Samples Collected: SD-SED-18A through E (core); SD-SED-18F (pint sample); 20 Jul 72 - #10989.
2. Location: West bank of Belle Fourche River, 17 m. downstream of bridge, 10 m. west of River, 12 km. east of Vale, S. D.; Butte County.
3. Occurrence of "Tailings": Tailings-like material occurs over extensive area of bank. Total depth of core hole: 1.68 m. Water encountered at 1 m.
4. Further description of material sampled: Total core from 1.68 m. hole in 5 increments plus top 15 cm. of 18E in pint jar (18F). See core log. Water collected for analyses (#20).
5. Relationship to Photo-Interpretation: In Area 50.

Site BF-6 T6N; R8E; SE, NW, 3 Volunteer Quad.

1. Samples Collected: SD-SED-19A and B; SD-SED-20A through G (core in pint samples) 20 Jul 72
2. Location: East bank of Belle Fourche River, 260 m. west of Volunteer, S. D. Sample SD-SED-19 collected 10 m. upstream of Highway 24 bridge, 6 m. east of River. Sample SD-SED-20 collected 35 m. downstream of bridge, 6 m. east of River edge (Meade County).
3. Occurrence of "Tailings": Tailings - like material occurs extensively over a mudflat which extends inshore about 30 meters. Silt depth decreases from a maximum of perhaps 2.5 meters (interbedded with sand and gravel) to a very thin deposit at extreme inshore locations.
4. Further description of material sampled: #19 - total depth 1.1 m.
   SD-SED-19A - dark, gray silt from lower 15 cm. of core; #10963
   SD-SED-19B - red and gray silt (10 cm. portion) found at about 45 cm. (deep); #10960

   #20 - total depth 2.1 to 2.2 m.

   SD-SED-20A - Upper 15 cm. of core; dark gray silt and clay; #10959
   SD-SED-20B - Portion from 15 cm. to 61 cm.; red, brown sand, 7 cm. to 10 cm. - thick layer below #20A; #10958
   SD-SED-20C - Portion from 61 cm. to 91 cm; red, brown sand with layers and lenses of dark gray silt - 12 cm. section of core; #10964

Site BF-6 (Cont.)

SD-SED-20D - Portion from 91 to 1.2 m.; dark gray silt with thin red, brown sand layers - 10 cm. section of core. #10961

SD-SED-20E - Portion from 1.2 m. to 1.5 m.; dark gray silt, wet area - 12 cm. from 15 cm. long silt layer. #10962

SD-SED-20F - Portion from 1.5 m. to 1.8 m.; Gravel layer mixed with dark gray silt but dry (20E was wet) - 10 cm. portion of core. #10965

SD-SED-20G - Portion from 1.8 m. to 2.1 or 2.2 m., thin-walled sampler jammed in hole; dry, tight, dark gray clay and silt, crumbles, (gravel at bottom of hole) - clay only sampled. #10969

5. Relationship to Photo Interpretation: Center of Area 109.

Site BF-7

T5N; R1E; NE, NW, SW 31 Hereford, SE Quad.

1. Samples Collected: SD-SED-13A and B (pint samples); SD-SED-13C through E (core); SD-SED-13F (core in pint sample); 19 Jul 72; A - #10972; B - #10973; F - #10984.

2. Location: North bank of Belle Fourche River, 6 m. upstream of bridge, 13 m. north of River, on road between Hereford and Viewfield, S. D. (Meade County).

3. Occurrence of "Tailings": Tailings - like material occurs to depth of 1 meter and less in a bank deposit. Dark gray silt is interbedded with red-brown sand.

4. Further description of material sampled:
SD-SED-13A - dark gray silt with red-brown sand from upper 15 cm. of column.
SD-SED-13B - red-brown sand found beneath 13A.
See core log for 13C - 13E.
SD-SED-13F - dark gray slimes, clayey silt, and rounded pebbles from about 1 meter (bottom of core hole); pebbles 0.6 to 1.2 cm diam.

5. Relationship to Photo Interpretation: Western portion of Area 209.

Site BF-8

T5N; R12E; NW, NE 34 and NE, SE, 26
Elm Springs SW Quad ("Mooney Ranch" Site)

1. Samples Collected: SD-SED-12A through F (pint samples); SD-SED-12G and H (core samples) 19 Jul 72.

2. Location: North bank of Belle Fourche River, 11 km. northwest of Elm Springs. Samples A through C collected beside River, Section 34. Samples D through H collected beside River, Section 26. (Meade County)

3. Occurrence of "Tailings": From experience of ranchers, gray silt occurs in "beds", separated by sand and gravel. Tailings - like material was found on the surface of bank deposits and was found in random widths. Samples were collected in close proximity (within 1 m.) to the River.

4. Further description of material sampled:
SD-SED-12A - dark gray silt with minor brown sand collected from selected layers in hand-dug pit to 30 cm. #10974
SD-SED-12B - black clayey silt with minor vegetative matter collected from bank-side slice of fresh river mud. #10975
SD-SED-12C - gray and brown sand and silt from surface at location 3 m. inshore from A and B. #10976
SD-SED-12D - dark gray silt with minor brown-red sand collected from 20 cm. to 23 cm. thick bed at depth of 30 cm. in hand dug pit at core site. #10977
SD-SED-12E - gray-green silt found at depth of 46 cm. in 15 cm.-thick layer encountered at hand dug pit at core site. #10970
SD-SED-12F - black and dark gray clay and organic (?) matter collected at depth of 30 cm. near core site. #10971
See core log

5. Relationship to Photo Interpretation: Samples A, B, C at east end of Area 237; Samples D-H at west end of Area 241.

Site BF-9 — T5N; R13E; NE, NE, 29 Elm Springs Quad.

1. Samples Collected: SD-SED-11A and B (pint samples); SD-SED-11C through G (core); SD-SED-11H and I (pint samples); 19 Jul 72.

2. Location: South bank of Belle Fourche River, 7 km. north-northwest of Elm Springs, S. D. Site for 11A located 17 m. upstream of bridge, 1 m. north of River. Site for 11B-G located 35 m. downstream of bridge, 5 m. south of River. Site for 11H located 35 m. downstream of bridge and 30 m. south of River at southern edge of silt deposits. Site for 11I located 100 m. downstream of bridge next to River (Meade County)

3. Occurrence of "Tailings": Tailings - like material covers bank deposit that extends downstream. Material also occurs in beds or layers at depth.

4. Further description of material sampled:
SD-SED-11A - gray and brown sands, minor fines, with dark gray silt in layers. #10978
SD-SED-11B - gray and brown sands predominate, with dark gray silt in layers. #10979
See core log for remainder (C thru G).
SD-SED-11H - surface mud (cracked) from 2.5 cm. layer of blackish, silty, surface material and red-brown sand from subsurface material. #10980
SD-SED-11I - dark gray, fresh silt, sticky, from layer beside River bank.#10981

5. Relationship to Photo-Interpretation: West edge of Area 249.

CHEYENNE RIVER

Site C-1 — T1N; R15E; NE, NW 4

1. Samples Collected: SD-SED-1 and SD-SED-2 (both pint samples); 17 Jul 72; #10955; #10954

2. Location: Southeast bank of Cheyenne River, 50 m. downstream of I-90 bridge, on gravel bar.

3. Occurrence of "Tailings": None. Silt is sparse in area.

4. Further description of material sampled:
SD-SED-1 - light gray silty sand with pebbles of same color - from upper 5 cm. to 7.5 cm. of surface (gravel and sand below).

SD-SED-2 - coarse sand, brown-gray, reddish, from beneath #1 in pit 60 cm. deep.

5. Relationship to Photo-Interpretation: No photography.

Site C-2

1. Samples Collected: SD-SED-21A through C (pint samples); 21 Jul 72.

2. Location: North bank of Cheyenne River, 30 m. upstream of S. D. Highway 34 bridge - A near River; B 8 m. north of River, C 33 m. north of River.

3. Occurrence of "Tailings": Gray silt occurs as relatively thin covering over gravel and sand bars and similar onshore deposits.

4. Further description of material sampled:
SD-SED-21A - dark gray silt, some sand, to depth of 20 cm. along River bank.#10968
SD-SED-21B - dark gray silt and sand, to depth of 5 cm. over gravel, from terrace about 8 m. higher than site for sample A. #10967
SD-SED-21C - gray silt from 10 cm. thick surface layer overlying white-brown sand in shallow abandoned (flood) channel north of River (lower area than site for sample B). #10966

5. Relationship to Photo-Interpretation: No photography.

TABLE 1 (Cont.)

CHEYENNE - ELK CREEK

Site CT-1 T3N; R13E; NE, SW, 1

1. Samples collected: SD-SED-3 (pint sample) - 17 Jul 72 - #10956
2. Location: South bank of Elk Creek at bridge 24 km. (road miles) north of Wasta and 7.2 km. south of Elm Springs; collected immediately downstream of bridge.
3. Occurrence of "Tailings": None
4. Further description of material sampled: Dark gray to black silt and red sand.
5. Relationship to Photo-Interpretation: No photography.

RESULTS OF METAL ASSAY FOR
MERCURY, ZINC, COPPER, AND ARSENIC IN RIVER ALLUVIUM COLLECTED FROM
WHITEWOOD CREEK, BELLE FOURCHE RIVER, AND CHEYENNE RIVER, SOUTH DAKOTA

JULY 1972

Sample Site Number	Water Course	Sediment Sample Number Field Lab	Type Material	Location Relative to Homestake	Sampled Depth (cm)	Metal Concentrations (mg/kg or ppm, dry weight)			
						Hg	Zn	Cu	As
WC-1	Whitewood Creek	SD-SRO-4 #10957	Red-brown sand, Dark silt	Downstream	15	<0.1	51.1	71.4	1600
WC-2	Whitewood Creek	SD-SED-5A #10952	Red-brown sand, Darker silt	Downstream	0-15	0.4	105.	103.	2600
"	" "	SD-SED-5B #10948	Gray-brown sand	Downstream	15-30	0.6	93.9	70.7	2100
WC-3	Whitewood Creek	SD-SED-14A #10983	Black organic material	Downstream	7 thick 50 beneath surface	<0.1	68.4	20.9	4.7
"	" "	SD-SED-14B #10982	Dark gray silt, minor sand	Downstream	0-10	<0.1	70.9	79.5	3000
"	" "	SD-SED-14C	Dark gray silt	Downstream	0-7	Container broken upon receipt at laboratory.			
"	" "	SD-SED-14D #10988	Yellow, green silt, sand	Downstream	0-25	1.0	70.4	38.5	1870
"	" "	SD-SED-14E #10987	Gray Clay, silt	Downstream	5 thick 25 beneath surface	2.0	44.4	33.3	4030
"	" "	SD-SED-14F #10986	Red-brown sand	Downstream	0-45	0.6	66.9	54.5	11770
WC-4	Whitewood Creek	SD-SED-15 #10985	Dark gray Silt, wet	Downstream	0-15	0.3	69.1	78.8	2730
WC-5	" "	SD-SED-6A #10950	Dark gray Silt	Downstream	7 thick 36 deep	4.1	104.	121.	4340

TABLE 2

TABLE 2 (cont.)

RESULTS OF METAL ASSAY FOR
MERCURY, ZINC, COPPER, AND ARSENIC IN RIVER ALLUVIUM COLLECTED FROM
WHITEWOOD CREEK, BELLE FOURCHE RIVER, AND CHEYENNE RIVER, SOUTH DAKOTA

JULY 1972

Sample Site Number	Water Course	Sediment Sample Number Field Lab	Type Material	Location Relative to Homestake	Sampled Depth (cm)	Metal Concentrations (mg/kg or ppm, dry weight)			
						Hg	Zn	Cu	As
WC-5	Whitewood Creek	SD-SED-6B	Dark gray Silt, sand (bar)	Downstream	7 thick 50 deep		Not analyzed		
WC-6	Whitewood Creek	SD-SED-7 #10953	Dark gray Silt, fine sand	Downstream	0-2	<0.1	53.3	60.1	1000
BF-1	Belle Fourche River	SD-SED-16A #10992	Gray-brown Silt, quartz, sand	Upstream	0-5	<0.1	77.9	18.8	10.7
"	" " "	SD-SED-16B #10991	Gray - clay, silt, quartz, and red-brown sand.	Upstream	15-20	<0.1	75.6	20.0	11.9
BF-2	" " "	SD-SED-17 #10990	Dark gray Silt, clay, sand	Upstream	0-20	0.1	86.3	21.6	12.6
BF-3	" " "	SD-SED-9A #10949	Dark gray Silt, clay, pebbles	Downstream	0-8	0.4	59.6	58.7	4760
"	" " "	SD-SED-9B #10951	Gray and brown Silt and sand	Downstream	8-20	0.5	81.7	57.8	1700
"	" " "	SD-SED-9C #10947	Brown-red Sand	Downstream	46-66	0.2	74.6	65.9	2000
BF-5	" " "	SD-SED-18F #10989	Dark gray Sand, silt	Downstream	153-168	0.5	55.9	72.9	2430
BF-6	" " "	SD-SED-19A #10963	Dark gray Silt	Downstream	295-310	0.8	75.7	115.	5260

RESULTS OF METAL ASSAY FOR
MERCURY, ZINC, COPPER, AND ARSENIC IN RIVER ALLUVIUM COLLECTED FROM
WHITEWOOD CREEK, BELLE FOURCHE RIVER, AND CHEYENNE RIVER, SOUTH DAKOTA

JULY 1972

Sample Site Number	Water Course	Sediment Sample Number Field Lab	Type Material	Location Relative to Homestake	Sampled Depth (cm)	Metal Concentrations (mg/kg or ppm, dry weight)			
						Hg	Zn	Cu	As
BF-6	Belle Fourche River	SD-SED-19B #10960	Red, gray Silt, sand	Downstream	40-50	1.4	82.4	59.7	1130
"	" " "	SD-SED-20A #10959	Dark gray Silt, clay	Downstream	0-15	0.2	68.6	67.4	1940
"	" " "	SD-SED-20B #10958	Red-brown Sand	Downstream	15-61	0.7	78.6	70.4	1830
"	" " "	SD-SED-20C #10964	Red-brown Sand, silt layers	Downstream	61-91	1.4	76.3	69.0	1980
"	" "	SD-SED-20D #10961	Dark gray Silt, sand layer	Downstream	91-120	0.8	89.1	65.2	1120
"	" " "	SD-SED-20E #10962	Dark gray Silt - wet	Downstream	120-150	1.2	89.9	74.2	1075
"	" " "	SD-SED-20F #10965	Gravel, silt	Downstream	150-180	0.1	84.2	28.9	120
"	" " "	SD-SED-20G #10969	Clay - dry	Downstream	180-210	<0.1	112	31.9	73.6
BF-7	Belle Fourche River	SD-SED-13A #10972	Dark gray Silt, clay, Red-brown sand	Downstream	0-15	0.8	77.0	92.9	2700
"	" " "	SD-SED-13B #10973	Red-brown Sand	Downstream	15-(30)	0.2	59.5	44.8	1275

TABLE 2 (cont.)

TABLE 2 (cont.)

RESULTS OF METAL ASSAY FOR
MERCURY, ZINC, COPPER, AND ARSENIC IN RIVER ALLUVIUM COLLECTED FROM
WHITEWOOD CREEK, BELLE FOURCHE RIVER, AND CHEYENNE RIVER, SOUTH DAKOTA

JULY 1972

Sample Site Number	Water Course	Sediment Sample Number Field Lab	Type Material	Location Relative to Homestake	Sampled Depth (cm)	Metal Concentrations (mg/kg or ppm, dry weight)			
						Hg	Zn	Cu	As
BF-7	Belle Fourche River	SD-SED-13F #10984	Dark gray Clay, silt, gravel	Downstream	~100	0.1	65.4	21.0	160
BF-8	Belle Fourche River	SD-SED-12A #10974	Dark gray Silt, clay Brown sand	Downstream	0-30	0.2	76.4	59.0	1740
"	" " "	SD-SED-12B #10975	Dark gray Silt, clay (fresh) Minor vegetation	Downstream	0-5	0.6	89.0	63.8	1200
"	" " "	SD-SED-12C #10976	Gray, brown Silt, sand	Downstream	0-15	0.2	64.3	63.2	2350
"	" " "	SD-SED-12D #10977	Dark gray Silt	Downstream	20 thick 30 deep	0.3	229.	145.	2880
"	" " "	SD-SED-12E #10970	Greenish silt, Clay	Downstream	15 thick 46 deep	0.7	73.7	65.8	1700
"	" " "	SD-SED-12F #10971	Dark Organic (?) material	Downstream	30	0.7	86.2	50.6	1025
BF-9	Belle Fourche River	SD-SED-11A #10978	Gray & brown Sand, silt	Downstream	0-30	0.2	69.0	49.0	1640
"	" " "	SD-SED-11B #10979	Red-brown Sand, silt	Downstream	0-30	0.5	76.9	65.3	1660
"	" " "	SD-SED-11H #10980	Black silt (i) and Red-brown sand (ii)	Downstream	0-2.5	0.4	101.	38.8	(i) 344 (ii) 1060

RESULTS OF METAL ASSAY FOR
MERCURY, ZINC, COPPER, AND ARSENIC IN RIVER ALLUVIUM COLLECTED FROM
WHITEWOOD CREEK, BELLE FOURCHE RIVER, AND CHEYENNE RIVER, SOUTH DAKOTA

JULY 1972

Sample Site Number	Water Course	Sediment Sample Number Field Lab	Type Material	Location Relative to Homestake	Sampled Depth (cm)	Metal Concentrations (mg/kg or ppm, dry weight)			
						Hg	Zn	Cu	As
BF-9	Belle Fourche River	SD-SED-11I #10981	Fresh dark gray Clay-silt	Downstream	0-10	0.4	118.	58.1	800
C-1	Cheyenne River	SD-SED-1 #10955	Light gray Silt	Upstream	5-7.5	<0.1	47.1	14.7	5.9
"	" "	SD-SED-2 #10954	Brown Sand	Upstream	7.5-60	<0.1	10.8	2.7	3.6
C-2	Cheyenne River	SD-SED-21A #10968	Gray, silt Minor sand	Downstream	0-20	0.3	81.9	31.3	460
"	" "	SD-SED-21B #10967	Dark gray Silt & sand	Downstream	0-5	0.1	60.4	23.4	350
"	" "	SD-SED-21C #10966	Gray silt White-brown sand	Downstream	0-10	0.1	70.6	33.1	370
CT-1	Elk Creek Tributary to Cheyenne River	SD-SED-3 #10956	Dark gray Silt, red sand	Upstream (separate minor watershed)	0-25	<0.1	96.9	25.1	16.6

TABLE 2 (cont.)

Based upon these stations, background concentrations of the metals of interest were as follows: Hg - 0.1 ppm (though one sample of silt from the Cheyenne River contained 0.3 ppm Hg); Zn - 10 to 100 ppm; Cu - 3 to 25 ppm; As - 4 to 17 ppm. In contrast, samples from other sites located downstream of the Homestake discharge contained as much as 4.1 ppm Hg, 229 ppm Zn, 145 ppm Cu, and 11,770 ppm As. All sediment concentrations are reported in dry weights. Measured moisture contents range from 1.6 to 68.8 percent.

All attempts to classify the sediments by their metal content must be tempered by cognizance of the limited number of samples collected for the express purpose of describing differences between lithologically-classified samples (48 one-pint samples plus 7 unanalyzed cores from 19 sites were collected). In the reaches of streams downstream of the Homestake operation, two types of alluvium predominate in the samples. First, a dark gray silt, black when wet and light gray when dry, was found over much of that part of the channel not covered by water. This material has been alleged to be relatively recent tailings from the Homestake gold mine and milling operation located at Lead, South Dakota. The second type of alluvium is a red-brown sandy-to-silty material which was often found beneath a surface layer of the dark silt and was also interbedded with the dark silt at certain sampling sites. The dark silt became lighter (toward brown) as one progressed downstream along the Belle Fourche River. The brown color is attributed to the presence of white and brown (oxide stained) quartz grains. No dark silt similar to that found in Whitewood Creek or in reaches of the Belle Fourche River downstream of Whitewood Creek was found either in the Belle Fourche River upstream of Whitewood Creek or in the Cheyenne upstream of the Belle Fourche River. Sands were generally more quartzite (lighter color) in these two upstream reaches, though at Site BF-1 on the Belle Fourche some red-brown sands were sampled. Some gray, slightly calcareous pebbles characteristic of weathered dolomites or massive shales were encountered in addition to quartzitic sands and pebbles.

Metal concentrations in the gray silt fraction versus the red sand fraction were compared in samples 14B and 14F collected at Site WC-3, samples 9A and 9C collected at Site BF-3, samples 19A and 19B collected at Site BF-6, samples 20A and 20B collected at Site BF-6, and samples 13F and 13B collected at Site BF-7. Comparison of these data indicates that while the red sand fractions may contain, on the average, about twice as much mercury as does the gray silt fractions, the other metals concentrations tend to vary widely. Specific silt and sand analyses of sample 11H (BF-9) suggest higher (x3) arsenic content in the red sand as compared to the gray silt at this location.

"Bottom of the core" (or relatively deep) samples #13F, 20F, and 20G, all had low arsenic and copper concentrations relative to higher (nearer surface) samples. These "bottom of the core" samples were

collected from gravels or from beneath gravels that often occur beneath the silts and sands. One sample of organic material with a black, silty clay character, was sampled from a steep stream bank above the creek at Site WC-2 (Sample 14A). This sample was found to contain a low mercury concentration (<0.1 ppm), an average zinc concentration (68.4 ppm), an average copper concentration (20.9 ppm), and a low arsenic concentration (4.7 ppm) when compared to "background" samples.

Another sample (#12F) was identified as "organic (?) material" in the field but the higher metal concentrations (than found in #14A) are thought to rule the organic content of 12F as significantly lower than sample 14A and instead to suggest the presence of tailings material in sample 12F. Since this 12F sample was collected from the fresh river bank, we are not surprised at the high metals content.

Average concentrations of metals in all samples (clay, silt, sand, and gravel) collected downstream of the Homestake operations were calculated to be:

Mercury:	≤0.6 ppm (<based on presence of 10% of samples containing less than 0.1 ppm) - 39 measurements.
Zinc:	81 ppm - 39 measurements
Copper:	63 ppm - 39 measurements
Arsenic:	2050 ppm - 40 measurements

When compared to the "background" concentrations presented earlier in this section (Hg - 0.1 ppm; Zn - 10 to 100 ppm; Cu - 3 to 25 ppm; As - 4 to 17 ppm), ambient concentrations in the sediments sampled from "downstream" locations have been increased as follows:

Mercury:	6-fold increase
Zinc:	No definitive change
Copper:	3-fold increase
Arsenic:	200-fold increase

Many of the alluvial sediments collected downstream of Whitewood Creek occur in an area where the Pierre Shale crops out. Thus, much alluvial material may be derived from these shales. H. A. Tourtelot (see Appendix I) has reported the following range in metal concentrations for the Pierre Shales:

Mercury:	Apparently not detected (≤1000 ppm)	
Zinc:	70-200 ppm (approximate)	mean: 140
Copper:	25-100 ppm (approximate)	
Arsenic:	5-41 ppm	mean: 14 ppm
Selenium:	1-50 ppm	mean: 18 ppm (one sample=50 ppm)

Comparison with the average concentration of metals in all samples collected downstream of the Homestake operations shows that the recently-measured samples contain metals, with the exception of arsenic, in concentrations within the range of concentrations occurring in the Pierre Shale. It is noteworthy that Tourtelot (ibid, p 50) concluded that higher arsenic, selenium, and molybdenum concentrations were to be found in the lower

(Sharon Springs) member of the Pierre Shale.

Of the metals measured, arsenic was present in the highest concentrations. The gold mined at Homestake occurs in close association with arsenopyrite (FeAsS). Thus, crushed ore at Homestake must contain high concentrations of arsenopyrite. Unless arsenic and iron pyrite are recovered the effluent should also contain high concentrations of arsenic, sulfur, and iron. Based upon our limited knowledge of the milling process utilized by Homestake, we presume that the arsenic and iron are still in the chemical form of arsenopyrite at the time of discharge.

In 1971, eighteen analyses of mercury in river alluvium sampled in the Belle Fourche River downstream of Whitewood Creek were made. The average mercury concentration of sediments in areas of suspected tailings as sampled at that time was 1.6 ppm[6]. The range in mercury concentrations measured in 1971 samples was quite similar to that measured in the 1972 samples, but the mean concentration was significantly higher (1.6 vs. 0.6 ppm) in the earlier samples. The median value for 1971 sediment samples was 1.4 ppm mercury while the median for 1972 sediment samples was 0.4 ppm mercury. Based on the 1971 data, it had been estimated[7] that certain tailings deposits in the lower reaches of Whitewood Creek contained about 1.8 grams of mercury per cubic meter. Based on the 1972 data, we estimate that the mercury content of the alluvial deposits of tailings sampled in 1972 average about 0.9 grams of mercury per cubic meter (based on an assumed sediment density of 1.5 gm/cm^3 and an average concentration of 0.6 ppm mercury). Utilizing the same 1972 data base, we can further estimate that the tailings contain, on the average, 120 grams of zinc per cubic meter (gm/m^3), 95 gm/m^3 of copper, and 3100 gm/m^3 of arsenic.

Random analyses of arsenic in sediment conducted by the Field Investigations staff averaged 2260 ppm, or quite close to the calculated average of 2050 ppm presented early in this section for the 1972 data.

It has been estimated that a total of 1100 hectares (hectare = 10^4 square meters) along Whitewood Creek and the Belle Fourche River upstream of the Cheyenne River contain tailings material[8]. If an average depth of tailings were known, total amounts of metals present could be estimated. However, the tailings occur in quite variable thicknesses and accurate estimates of thickness are beyond the scope of this report since such determinations would require powered drilling equipment.

The study could obtain no assistance in determing in situ leaching rates for the alluvial materials. The metals data do suggest a general decrease in the metals content of the sediment as one progresses downstream. This is evident in the mercury and copper data and less evident in the arsenic and zinc data. Such a decrease may be caused by leaching as well as by dilution with sediments from other watersheds containing lower concentrations of mercury and copper.

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6) pp 65 and 82-3 of report referenced in footnote 2.
7) p 31 of report referenced in footnote 2.
8) p 6 of report referenced in footnote 3.

Ground Water Samples

In accordance with Recommendation #7 previously presented in the Introduction, an effort was made to determine the amount of arsenic present in shallow wells extant along the drainage channels of Whitewood Creek, the Belle Fourche, and the Cheyenne Rivers. In further accord with Conclusion #4 of the investigative report (presented and referenced in the Introduction to this report), mercury, zinc, and copper were added to the analyses since these materials were reported to be discharged, either "presently" or in the past, from the Homestake operation. In addition, selenium assays were included at the request of the conferees since naturally-introduced selenium has been measured in significant quantities in the geographical area.

A total of 19 wells were located and sampled (one of these was dug during the sediment survey). Samples were collected from most wells at four different times--December (1971), March, July, and October (1972). Mr. Al Foster, then with the State of South Dakota Health Department, assisted with the majority of the effort. A total of 13 sites were located downstream of the Homestake fluid discharge. A total of six sites were selected to sample water not associated or influenced by any fluid discharge from the Homestake operations. One surface water sample was collected, in July and October 1972, from Whitewood Creek near Whitewood, South Dakota. The sampling locations are described in Table 3.

Essentially all active wells located near the water courses in question and completed in the relatively shallow river alluvium were sampled. With the advent of the Butte Meade Sanitary District water supply, there appears to be a number of recently abandoned shallow wells throughout the area, especially near Whitewood Creek. "Active" wells were scarce.

Spectographic analyses of five samples were accomplished by the EPA Analytical Quality Control Laboratory in Cincinnati, Ohio. The results of these analyses are presented in Table 4. Detectable quantities of zinc, boron, iron, manganese, copper, vanadium[9]), and barium were measured. Trace or "not detectable" concentrations were measured for cadmium, aluminum, beryllium, silver, nickel, cobalt, lead, and chromium. In terms of water quality standards for the designated uses (domestic and stock), no well-defined problems or excesses were evident.

The results of quarterly assays for mercury, zinc, copper, arsenic, and selenium are presented in Table 5. Note that different methods of sample preservation were employed. One method was essentially no preservation ("raw") for samples utilized in Hg, Zn, Cu, As, and Se assay. Replicate samples collected in July and October were filtered in the field through 0.45 micron filter material and were acidified with a 10% solution of nitric acid (5 ml HNO_3 per liter) for subsequent Hg, Zn, Cu, and As assay. Replicate samples for selenium assay were similarly filtered and iced. All samples for cyanide assay were treated with sodium hydroxide to raise the pH to about 11 (S.U.) and were refrigerated. Cyanide analyses were accomplished within two days of sample collection. Assay of "raw" samples may reflect metal concentrations in the suspended as well as the dissolved fraction of the sample.

Samples were collected quarterly in an attempt to reflect different pumping rates and, therefore, different or larger sources of water.

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9) The occurrence of vanadium in water samples is considered rare.

TABLE 3

Description of Water Sampling Sites and Samples Collected along Whitewood Creek, Belle Fourche River, and Cheyenne River, South Dakota

(December 1971 - October 1972)

WHITEWOOD CREEK (& WHITETAIL CREEK)

Site 1 — T4N; R3E; SW, NE, 5 Lead Quad.

1. Samples collected: 1 Dec 71; 20 Mar 72; 18 Jul 72; 16 Oct 72.
2. Location: Phil Martin's Conoco Station, about 2 km. SW of Glory Hole at Lead, S. D., on U. S. Highway 85 and Alt. 14, west side of road, 75 m. west of Whitetail Creek, a tributary (perennial) of Whitewood Creek, outside office.
3. Description of well: Shallow well reportedly blasted along fracture plane of igneous/metamorphic rock. Hand pumped. Used for domestic and other purposes.

Site 2 — T4N; R3E; SW, NE, 5 Lead Quad.

1. Samples collected: 1 Dec 71; 20 Mar 72; 18 Jul 72; 16 Oct 72.
2. Location: E. O. Franzel - General Services Garage, about 2.1 km SW of Glory Hole at Lead, S. D., on U. S. Highway 85 and Alt. 14, west side of road, 100 m. west of Whitetail Creek, a tributary of Whitewood Creek, inside garage.
3. Description of well: Shallow well, construction unknown. Probably in rock similar to well of Site 1. Pressure pumped; used for domestic and other purposes. Sampled from outlet in garage area.

Site 3 — T6N; R4E; NE, NE, 33 Deadwood North Quad.

1. Samples collected: 1 Dec 71; 20 Mar 72; 18 Jul 72; 16 Oct 72.
2. Location: Clifford Johnson Residence, located about 1.3 km. south of center of Whitewood, S. D., near site of Crook City, 300 m. NW of Whitewood Creek and Sediment Site WC-1, on east side of divide from Centennial Prairie, inside house.
3. Description of well: Shallow to medium (ca. 20 m) depth well, probably completed in stream alluvium. Pressure pumped, used for domestic purposes. Sampled from inside and outside outlets. (outside in July 1972).

Site 4 — T6N; R4E; NE, SW, 15 Sturgis Quad.

1. Samples collected: 1 Dec 71; 20 Mar 72; 18 Jul 72; 16 Oct 72.
2. Location: Charles Wennberg Farm, about 2.5 km. NNE of the center of Whitewood, S. D., on east side of "Whitewood Valley Road," about 300 m. east of Whitewood Creek, in valley, near farm buildings.
3. Description of well: Shallow well completed in alluvium. Pressure pumped. Used for stock watering.

Site 5 — T6N; R4E; SW, NE, 2 Sturgis Quad.

1. Samples collected: 1 Dec 71; 18 Jul 72; 16 Oct 72.
2. Location: William Alan Ranch, about 4.4 km. NNE of the center of Whitewood, S. D., on west side of "Whitewood Valley Road," about 200 m. east of Whitewood Creek, in valley, inside corral.
3. Description of well: Shallow dug well completed in alluvium, pressure pumped, used for stock.

TABLE 3 (Cont.)

Site 6

T7N; R4E; SE, NW, 25 Saint Onge, SE Quad.

1. Samples collected: 1 Dec 71; 20 Mar 72; 18 Jul 72; 16 Oct 72.

2. Location: Ike Ala Ranch, about 7 km. NNE of center of Whitewood, S. D., 300 m. east of Whitewood Creek across low hill, west side of Whitewood Valley Road, inside house.

3. Description of well: Shallow well of unknown completion (probably alluvium), pressure pumped, used for domestic purposes.

BELLE FOURCHE RIVER

Site 16

(Specific location of supply not determined.)

1. Samples collected: 20 Mar 72; 18 Jul 72; 16 Oct 72.

2. Location: Sampled at Ezra Pauley Ranch - Belle-Meade District Water Supply (See Site 8).

3. Description: Surface water supply from Belle Fourche Reservoir, upstream of Whitewood Creek.

Site 7

T8N; R6E; SW, SW, 20 Newell Quad.

1. Samples collected: 1 Dec 71; 20 Mar 72; 18 Jul 72; 16 Oct 72.

2. Location: Leo Harr Stock Well, about 9 km. south of Newell, S. D., on east side of State Highway 79, 75 m. north of Belle Fourche River in corral area, in flood plain.

3. Description of well: Shallow (dug) hand-pumped well, completed in river alluvium, used for stock watering.

Site 8

T8N; R6E; SE, NW, 20 Newell Quad.

1. Samples collected: 1 Dec 71; 18 Jul 72, 16 Oct 72.

2. Location: Ezra Pauley Ranch, about 1.8 km. NE of Vale, S. D., 500 m. SE of Belle Fourche River, immediately above the close-in flood plain.

3. Description of well: Shallow (~7m.) well completed in alluvium, formerly domestic water supply; not now used.

Site 15

T7N; R8E; NW, SW, 28 Volunteer Quad.

1. Samples collected: 2 Dec 71; 20 Mar 72; 19 Jul 72; 16 Oct 72.

2. Location: Fred Schummer Ranch, about 4.5 km. NW of Volunteer, S. D., and 2.5 km. north of State Highway 24, 500 m. west of Belle Fourche River beside minor tributary to Belle Fourche River.

3. Description of well: Shallow well, probably completed in alluvium, pressure pumped, used for domestic purposes.

Site 14

T6N; R8E; SE, SE, 2 Volunteer Quad.

1. Samples collected: 2 Dec 71; 20 Mar 72; 19 Jul 72; 16 Oct 72.

2. Location: David Richards Residence, about 700 m. SE of Volunteer, S. D., on south side of State Highway 24, 150 m. north of Belle Fourche River on bluff above river.

3. Description of well: Shallow well, completion not known, used for domestic purposes; pressure pumped.

TABLE 3 (Cont.)

Site 13 — T6N; R8E; SE, SE, 2 Volunteer Quad.

1. Samples collected: 2 Dec 71; 20 Mar 72; 19 Jul 72; 16 Oct 72.
2. Location: David Richards Farm, about 750 m. SE of Volunteer, S. D., on south side of State Highway 24, 75 m. north of Belle Fourche River, on bluff above river.
3. Description of well: Shallow (dug) well, completed in alluvium, pressure pumped, used for stock watering.

Site 18 — T6N; R8E; SE, SE, 2 Volunteer Quad.

1. Samples collected: 19 Jul 72; 16 Oct 72.
2. Location: David Richards Farm - Tenants' House, about 800 m. SE of Volunteer, S. D., on south side of State Highway 24, 75 m. north of Belle Fourche River, on bluff above river.
3. Description of well: Shallow well, completed in alluvium, pressure pumped, used for domestic purposes.

Site 17 — T5N; R12E; SE, SW, 27 Elm Springs, SW Quad.

1. Samples collected: 21 Mar 72; 19 Jul 72; 17 Oct 72.
2. Location: Mooney Ranch, about 11.2 km. NW of Elm Springs, 6.5 km. upstream of Elm Springs, S. D., road bridge across Belle Fourche River, 300 m. east and 600 m. north of Belle Fourche River, in flood plain.
3. Description of well: Shallow (dug) stock well, pumped.

Site 12 — T5N; R12E; SE, SW, 27 Elm Springs, SW Quad.

1. Samples collected: 2 Dec 71; 21 Mar 72; 19 Jul 72; 17 Oct 72.
2. Location: Mooney Ranch about 11.2 km NW of Elm Springs, S. D., 6.5 km. upstream of Elm Springs road bridge across Belle Fourche River, 300 m. NE of Belle Fourche River, in flood plain.
3. Description of well: Shallow (dug) well, completed in alluvium, pressure pumped, used for stock watering.

Site 20 (Sediment Site BF-5) — T8N; R7E; SE, NW, 27 Vale NE Quad.

1. Samples collected: 20 Jul 72.
2. Location: West bank of Belle Fourche River, 17 m. downstream of bridge, 10 m. west of river, 12 km. east of Vale, S. D.
3. Description of well: Shallow (1.2 m.), dug well at bottom of core hole. Water encountered at 1 m.

CHEYENNE RIVER

Site 9 — T1N; R14E; NW, NE, 9 Wasta Quad.

1. Samples collected: 2 Dec 71; 21 Mar 72; 19 Jul 72, 17 Oct 72.
2. Location: Interstate-90 Rest Area, eastbound side, about 1 km. SE of Wasta, S. D., and 400 m. SE of Belle Fourche River. Water supplied either from shallow wells or springs in near vicinity.
3. Description: Water supply from springs/wells in vicinity of Wasta, S. D., used for domestic purposes.

TABLE 3 (Cont.)

Site 10 — T1N; R14E; NE, SE, 2 Wasta Quad.

1. Samples collected: 2 Dec 71; 21 Mar 72; 19 Jul 72; 17 Oct 72.
2. Location: Dean Schell Ranch, about 4.2 km east of Wasta, S. D., 600 m. east of Belle Fourche River, beside Bull Creek and in flood plain of Belle Fourche River.
3. Description of well: Shallow well, probably completed in alluvium, pressure pumped, used for domestic purposes.

Site 11 (Bull Creek) — T1N; R15E; SW, SW, 7 Wasta, SE Quad.

1. Samples collected: 2 Dec 71; 21 Mar 72; 19 Jul 72; 17 Oct 72.
2. Location: Jerry Schell Ranch, about 7.4 km. SE of Wasta, S. D., on west side of Interstate 90, about 4 km. SE of Belle Fourche River beside intermittent tributary to Belle Fourche River (Bull Creek).
3. Description of well: Shallow well, unknown completion, pressure pumped, used for stock water and formerly for domestic purposes (Dec 71). Note: Well not used for stock since stock well apparently detrimentally affected by either the water or locally-grown feed.

WHITEWOOD CREEK - SURFACE WATER

Site 19 (Sediment Site WC-2) — T6N; R4E; NW, NW, 22 Sturgis Quad.

1. Samples collected: 20 Jul 72; 16 Oct 72.
2. Location: Whitewood Creek at crossing of Whitewood Valley Road, 1.2 km. north of Whitewood, S. D. (new location of road on Sturgis Quad.).

TABLE 4

RESULTS OF SPECTROGRAPHIC ANALYSIS OF
SELECTED WATER SAMPLES COLLECTED FROM SHALLOW WELLS
ALONG WHITEWOOD CREEK, BELLE FOURCHE RIVER, AND CHEYENNE RIVER

December 1971[1)]

Sample Location (Site) No.	Water Use	Stream Nearby	Total Concentrations (mg/l)														
			Zn	Cd	B	Fe	Mn	Al	Be	Cu	Ag	Ni	Co	Pb	Cr	V	Ba
5	Stock	Whitewood Creek	0.040 (0.084[2)])	<0.020	0.080	0.040	0.160	<0.040	<0.0001	0.020 (<0.01)	<0.002	<0.020	<0.020	0.080	<0.020	0.040	0.006
8	Domestic (not used)	Belle Fourche River	0.080 (0.155)	<0.040	0.600	0.080	<0.040	<0.080	<0.0002	<0.040 (<0.01)	<0.004	<0.040	<0.040	<0.080	<0.040	0.080	0.008
14	Stock	Belle Fourche River	<0.020 (0.060)	<0.020	0.400	0.200	0.400	<0.040	<0.0001	<0.020 (<0.01)	<0.002	<0.020	<0.020	<0.040	<0.020	<0.040	<0.004
10	Domestic	Cheyenne River	0.190[3)] (0.335)	<0.050	0.580	<0.050	<0.050	<0.100	<0.0003	0.052 (0.04)	<0.005	<0.050	<0.050	<0.100	<0.050	<0.100	<0.010
11	Stock and Domestic	Cheyenne River (Bull Creek)	<0.050 (0.006)	<0.050	0.850	<0.050	0.090	<0.100	<0.0003	0.050 (0.05)	<0.005	<0.050	<0.050	<0.100	<0.050	0.100	0.010

1) Analyses by EPA Analytical Quality Central Laboratory - samples neither filtered nor preserved.
2) Analyses of replicate samples by EPA Region VIII Laboratory - samples neither filtered nor preserved.
3) Average of two (replicate) analyses for all parameters.

TABLE 5

RESULTS OF CHEMICAL ASSAY FOR
MERCURY, ZINC, COPPER, ARSENIC, SELENIUM, AND CYANIDE
IN WATER SAMPLES COLLECTED FROM SHALLOW WELLS ALONG
WHITEWOOD CREEK, BELLE FOURCHE RIVER, AND CHEYENNE RIVER, SOUTH DAKOTA

(December 1971 - October 1972)

Sample Location (Site) No.	Water Use	Location Relative to Homestake	Stream Nearby	MERCURY (µg/l)							ZINC (mg/l)						
				Dec 71 Raw	Mar 72 Raw	JUL 72 Filtered HNO_3	JUL 72 Raw	OCT 72 Filtered HNO_3	OCT 72 Raw	Mean*	Dec 71 Raw	Mar 72 Raw	JUL 72 Filtered HNO_3	JUL 72 Raw	OCT 72 Filtered HNO_3	OCT 72 Raw	Mean
1	Domestic	Upstream	Whitewood Creek	<0.20	<0.2	0.23	<0.2	<0.20	<0.20	≤0.20	0.058	0.97	0.022	0.020	0.060	0.025	0.19
2	Domestic	Upstream	Whitewood Creek	<0.20	<0.2	0.28	<0.2	<0.20	0.21	≤0.21	0.705	0.28	0.400	0.380	0.380	0.710	0.48
3	Domestic	Downstream	Whitewood Creek	<0.20	0.3	0.33	<0.2	<0.20	0.25	≤0.25	0.018	<0.05	0.024	<0.005	0.045	0.010	≤0.02
4	Stock	Downstream	Whitewood Creek	<0.20	0.4	0.38	<0.2	<0.20	0.21	0.26	0.390	0.13	0.550	<0.006	0.220	0.170	0.24
5	Stock	Downstream	Whitewood Creek	<0.20	N/S	0.38	<0.2	<0.20	0.21	≤0.24	0.084	N/S	0.130	<0.005	0.250	0.025	0.10
6	Domestic	Downstream	Whitewood Creek	<0.20	<0.2	0.38	<0.2	<0.20	0.21	≤0.23	0.150	0.14	0.150	<0.005	0.060	0.040	0.09
16	Domestic	Upstream	Butte-Meade San.Dist. (Deep wells)	N/S	<0.2	0.40	<0.2	<0.20	<0.20	≤0.20	N/S	0.11	0.026	<0.005	0.060	0.130	0.07
7	Stock	Downstream	Belle Fourche River	<0.20	<0.2	(1.46) Suspect	0.26	<0.20	<0.20	≤0.21	0.725	0.28	0.570	0.009	0.340	0.020	0.32
8	Domestic (not used)	Downstream	Belle Fourche River	<0.20	N/S	0.54	<0.2	<0.20	<0.20	≤0.27	0.155	N/S	0.013	<0.005	0.150	0.025	0.07
15	Domestic	Downstream	Belle Fourche River	0.21	<0.2	0.61	<0.2	<0.20	0.21	≤0.27	0.550	0.22	0.640	<0.005	0.460	0.590	0.41
14	Stock	Downstream	Belle Fourche River	<0.20	<0.2	0.65	<0.2	<0.20	<0.20	≤0.27	0.060	0.74	0.140	<0.005	0.150	0.020	0.18
13	Domestic	Downstream	Belle Fourche River	<0.20	<0.2	0.56	<0.2	<0.20	<0.20	≤0.26	0.695	0.72	0.110	0.640	0.400	0.310	0.48
18	Domestic	Downstream	Belle Fourche River	N/S	N/S	0.76	<0.2	0.21	<0.20	≤0.34	N/S	N/S	0.540	0.150	0.040	0.015	0.19
17	Stock	Downstream	Belle Fourche River	N/S	<0.2	0.57	0.30	<0.20	<0.20	≤0.29	N/S	<0.05	<0.005	0.032	0.025	0.070	≤0.04
12	Stock	Downstream	Belle Fourche River	<0.20	0.2	0.56	0.22	<0.20	<0.20	≤0.26	0.013	0.08	0.050	0.053	0.030	0.040	0.04
9	Domestic	Upstream	Cheyenne River	<0.20	<0.2	0.48	<0.2	<0.20	<0.20	≤0.25	0.420	0.28	0.150	0.140	0.490	0.480	0.33
10	Domestic	Upstream	Cheyenne River	<0.20	<0.2	0.56	<0.2	<0.20	<0.20	≤0.26	0.335	0.64	0.240	0.370	0.210	0.130	0.32
11	Stock & Domestic	Upstream	Cheyenne River (Bull Creek)	<0.20	0.2	0.56	<0.2	<0.20	<0.20	≤0.26	0.006	0.18	0.044	<0.005	0.120	0.075	0.07
20	Dug well	Downstream	Belle Fourche River (BF-5)	N/S	N/S	0.60	N/S	N/S	N/S	0.60	N/S	N/S	0.046	N/S	N/S	N/S	0.05
19	Surface Water	Downstream	Whitewood Creek	N/S	N/S	0.50	1.50	<0.20	5.48	≤0.35/ 3.49**	N/S	N/S	0.006	<0.005	0.022	<0.010	≤0.01

*See text.
**Filtered/unfiltered.
N/S = Not sampled.

TABLE 5 (Cont.)

RESULTS OF CHEMICAL ASSAY FOR
MERCURY, ZINC, COPPER, ARSENIC, SELENIUM, AND CYANIDE
IN WATER SAMPLES COLLECTED FROM SHALLOW WELLS ALONG
WHITEWOOD CREEK, BELLE FOURCHE RIVER, AND CHEYENNE RIVER, SOUTH DAKOTA

(December 1971 - October 1972)

Sample Location (Site) No.	Water Use	Location Relative to Homestake	Stream Nearby	COPPER (mg/l)							ARSENIC (mg/l)						
				Dec 71 Raw	Mar 72 Raw	JUL 72 Filtered HNO_3	JUL 72 Raw	OCT 72 Filtered HNO_3	OCT 72 Raw	Mean	Dec 71 Raw	Mar 72 Raw	JUL 72 Filtered HNO_3	JUL 72 Raw	OCT 72 Filtered HNO_3	OCT 72 Raw	Mean
1	Domestic	Upstream	Whitewood Creek	<0.01	0.02	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.01	<0.010	<0.010	<0.005	<0.005	<0.01
2	Domestic	Upstream	Whitewood Creek	<0.01	<0.02	<0.005	0.010	0.006	<0.005	<0.01	<0.01	<0.01	<0.010	<0.010	<0.005	<0.005	<0.01
3	Domestic	Downstream	Whitewood Creek	<0.01	0.06	<0.005	<0.005	0.019	0.005	<0.02	<0.01	<0.01	<0.010	<0.010	0.005	<0.005	<0.01
4	Stock	Downstream	Whitewood Creek	<0.01	<0.02	<0.005	<0.005	0.010	<0.005	<0.01	<0.01	<0.01	<0.010	<0.010	0.005	0.005	<0.01
5	Stock	Downstream	Whitewood Creek	<0.01	N/S	0.027	<0.005	0.014	0.006	<0.01	0.01	N/S	<0.010	<0.010	0.006	<0.005	<0.01
6	Domestic	Downstream	Whitewood Creek	<0.01	<0.02	0.005	<0.005	0.006	0.006	<0.01	<0.01	<0.01	<0.010	<0.010	0.005	<0.005	<0.01
16	Domestic	Upstream	Butte-Meade San.Dist. (Deep wells)	N/S	0.14	0.011	0.012	0.032	0.054	0.05	N/S	<0.01	<0.010	<0.010	<0.005	0.005	<0.01
8	Stock	Downstream	Belle Fourche River	<0.01	<0.02	0.006	<0.005	0.024	0.018	<0.01	0.02	<0.01	<0.010	<0.010	0.005	0.010	0.01
9	Domestic (not used)	Downstream	Belle Fourche River	<0.01	N/S	0.007	0.013	0.013	0.010	0.01	0.01	N/S	<0.010	<0.010	<0.005	<0.005	<0.01
14	Domestic	Downstream	Belle Fourche River	0.02	0.02	0.005	<0.005	0.010	0.010	0.01	<0.01	<0.01	<0.010	<0.010	<0.005	0.005	<0.01
15	Stock	Downstream	Belle Fourche River	<0.01	0.02	<0.005	<0.005	0.024	0.020	<0.01	0.03	<0.01	<0.010	<0.010	<0.005	0.005	0.01
17	Domestic	Downstream	Belle Fourche River	<0.01	0.02	<0.005	<0.005	0.016	0.010	<0.01	<0.01	<0.01	<0.010	<0.010	<0.005	<0.005	<0.01
18	Domestic	Downstream	Belle Fourche River	N/S	N/S	<0.005	0.007	0.018	0.010	0.01	N/S	N/S	<0.010	<0.010	0.005	0.005	<0.01
7	Stock	Downstream	Belle Fourche River	N/S	<0.02	0.005	0.008	0.022	0.010	0.01	N/S	<0.01	<0.010	<0.010	<0.005	<0.005	<0.01
12	Stock	Downstream	Belle Fourche River	<0.01	<0.02	0.006	0.006	0.014	0.007	0.01	0.03	0.02	<0.010	<0.010	0.005	<0.005	0.01
13	Domestic	Upstream	Cheyenne River	0.05	0.09	0.041	0.029	0.062	0.050	0.05	<0.01	<0.01	<0.010	<0.010	<0.005	<0.005	<0.01
10	Domestic	Upstream	Cheyenne River	0.04	0.06	0.016	0.018	0.016	0.010	0.03	<0.01	<0.01	<0.010	<0.010	<0.005	<0.005	<0.01
11	Stock & Domestic	Upstream	Cheyenne River (Bull Creek)	0.05	0.05	0.014	0.006	0.024	0.010	0.02	<0.01	<0.01	<0.010	<0.010	0.005	<0.005	<0.01
20	Dug well	Downstream	Belle Fourche River (BF-5)	N/S	N/S	0.044	N/S	N/S	N/S	0.04	N/S	N/S	4.080	N/S	N/S	N/S	4.08
19	Surface Water	Downstream	Whitewood Creek	-	-	0.058	<0.005	0.034	0.006	0.02	-	-	0.107	0.090	0.320	0.060	0.14

N/S = Not sampled.

TABLE 5 (Cont.)

RESULTS OF CHEMICAL ASSAY FOR
MERCURY, ZINC, COPPER, ARSENIC, SELENIUM, AND CYANIDE
IN WATER SAMPLES COLLECTED FROM SHALLOW WELLS ALONG
WHITEWOOD CREEK, BELLE FOURCHE RIVER, AND CHEYENNE RIVER, SOUTH DAKOTA

(December 1971 - October 1972)

Sample Location (Site) No.	Water Use	Location Relative to Homestake	Stream Nearby	SELENIUM (mg/l)					CYANIDE (mg/l)			
				Dec 71 Raw	Mar 72 Raw	Jul 72 Filtered (Iced)	Oct 72 Filtered (Iced)	Mean	Mar 72 **	Jul 72	Oct 72	Mean
1	Domestic	Upstream	Whitewood Creek	<0.002	0.002	0.005	0.002	0.002	<0.02	<0.05	<0.01	<0.02
2	Domestic	Upstream	Whitewood Creek	<0.002	<0.002	<0.002	0.002	<0.002	<0.02	<0.05	<0.01	<0.02
3	Domestic	Downstream	Whitewood Creek	<0.002	<0.002	0.002	0.004	0.002	<0.02	<0.05	<0.01	<0.02
4	Stock	Downstream	Whitewood Creek	<0.002	<0.002	0.002	0.002	0.002	<0.02	<0.05	<0.01	<0.02
5	Stock	Downstream	Whitewood Creek	<0.002	N/S	0.002	<0.002	<0.002	N/S	<0.05	<0.01	<0.02
6	Domestic	Downstream	Whitewood Creek	<0.002	0.003	0.002	0.003	0.002	<0.02	<0.05	<0.01	<0.02
16	Domestic	Upstream	Butte-Meade San.Dist. (Deep wells)	N/S	0.003	<0.002	<0.002	≤0.002	<0.02	<0.05	<0.01	<0.02
7	Stock	Downstream	Belle Fourche River	<0.002	<0.002	<0.002	0.003	<0.002	<0.02	<0.05	<0.01	<0.02
8	Domestic (not used)	Downstream	Belle Fourche River	0.002	N/S	<0.002	0.002	<0.002	N/S	<0.05	<0.01	<0.02
15	Domestic	Downstream	Belle Fourche River	<0.002	<0.002	<0.002	<0.002	<0.002	<0.02	<0.05	<0.01	<0.02
14	Stock	Downstream	Belle Fourche River	0.003	0.002	0.008	0.007	0.005	<0.02	<0.05	<0.01	<0.02
13	Domestic	Downstream	Belle Fourche River	0.021	0.013	0.016	0.016	0.018	<0.02	<0.05	<0.01	<0.02
18	Domestic	Downstream	Belle Fourche River	N/S	N/S	0.006	0.002	0.004	N/S	<0.05	<0.01	<0.02
17	Stock	Downstream	Belle Fourche River	N/S	I*	0.022	0.015	0.018	<0.02	<0.05	<0.01	<0.02
12	Stock	Downstream	Belle Fourche River	<0.002	0.012	0.013	0.015	0.010	<0.02	<0.05	<0.01	<0.02
9	Domestic	Upstream	Cheyenne River	0.010	0.010	0.005	0.005	0.008	<0.02	<0.05	<0.01	<0.02
10	Domestic	Upstream	Cheyenne River	0.005	0.006	0.004	0.004	0.005	<0.02	<0.05	<0.01	<0.02
11	Stock & Domestic	Upstream	Cheyenne River (Bull Creek)	0.009	0.010	0.007	0.004	0.008	<0.02	<0.05	<0.01	<0.02
20	Dug well	Downstream	Belle Fourche River (BF-5)	N/S	N/S	N/S	N/S	-	N/S	N/S	N/S	-
19	Surface Water	Downstream	Whitewood Creek	-	-	<0.002	<0.002	<0.002	N/S	N/S	0.30	0.30

N/S = Not sampled.
* = Interference (high suspended material)
** = Analyses by So. Dak. Engineering & Mining Experiment Station, Rapid City.

TABLE 5 (cont.)

However, the early summer months were generally wetter than normal and pumping rates are considered to have remained the same throughout the sampling period. Wells were not pumped extensively prior to actual sampling since our purpose was to measure concentrations in the water at the time the water was used.

The surface water samples collected from Whitewood Creek[10] in July and October show significant mercury (compared to well samples) in the suspended portion of the samples (avg. 3.5 µg/l). As will be explained later, no wells sampled are believed to have contained significant concentrations of mercury. This surface water collected in October 1972 provided the only water sample found to contain cyanide with its single analysis indicating 0.30 mg/l CN, a concentration in excess of 0.02 mg/l, the "allowable concentration of trace ions in farmstead waters." To our knowledge, the waters of Whitewood Creek represented by this single analysis are not used. No well, as sampled, contained detectable cyanide (Table 5). Zinc and copper were detected in these surface waters (Whitewood Creek) at concentrations averaging ≤0.01 mg(Zn)/l and 0.02 mg (Cu)/l, both of which appear low. Arsenic was detected at as high a concentration as 0.32 mg/l and averaged 0.14 mg/l. Both concentrations are in excess of the recommended limit for domestic and stock use of 0.05 mg/l.

Prior to summarizing the metals data for the subsurface waters, attention must be called to the mercury concentrations measured for filtered and acidified "HNO_3" samples collected in July 1972 (Table 5). Of all the analyses conducted, only this July set showed readily detectable quantities of mercury. The consistency of the concentrations determined for these July samples leads us to suspect that they have all been contaminated, probably by the preservative, nitric acid. We have insufficient information to derive any other reason, such as infiltration of mercury-laden ground or surface water, to account for the rise in all samples. Reinforcing the contamination hypothesis is the fact that the well at Site 8 was not used during the sampling period (December 1971 through October 1972) and, thus, an anomalously high value reported for its July 1972 sample (0.54 µg/l) is suspect. If the mercury contamination were accompanied by zinc, copper, or arsenic contamination, the decreased sensitivity for the latter metals could prevent detection.[11] It is recommended that a few samples be collected from these wells in July 1973, to verify the absence of any large increase in mercury concentrations, an absence we have assumed for this report.

As noted earlier, neither mercury nor cyanide was detected in either notable or consistently detectable quantities, in any wells, either upstream or downstream of the Homestake operations. Minor concentrations of mercury were detected in a few "raw" samples, indicating that some mercury was present in the suspended fractions of the samples. Arsenic was measured as present to the extent of 0.03 mg/l at two wells in December 1971 (Sites 14 and 12) and at 0.02 mg/l in December 1971 at one site (7) and again in March 1972 at Site 12. July and October samples

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10) Surface water samples collected downstream from the Homestake operations.
11) Analytical methods used for zinc, copper, and arsenic often have sensitivities on order of magnitude higher (less sensitive) than that used for mercury assay.

contained essentially no arsenic (<0.01 mg/l). The higher concentrations approach, but do not exceed, the recommended limit of 0.05 mg As/l for domestic and stock use. Site 12 may deserve periodic checking for arsenic. A well dug in tailings contained water with a dissolved concentration of 4 mg As/l (Site BF-5; sediment contained 2430 ppm As).

Selenium was found to be present in moderately high concentrations in the lower Belle Fourche River and Cheyenne drainages. The highest concentration measured in the Whitewood Creek drainage was 0.005 mg/l (at Site 1). The domestic well at Site 13, on the Belle Fourche River, contained the highest concentration in domestic water (0.21 mg Se/l in December 1971) and the selenium concentration averaged 0.18 mg/l at Site 13. The stock well at Site 17 showed the highest single value for stock water (0.22 mg Se/l in July 1972) and also averaged (2 samples) 0.18 mg Se/l. All of these values exceed the recommended limit concentration for selenium (0.01 mg/l). Also exhibiting concentrations equal to or in excess of the limit concentration were samples from Sites 12, 9, and 11.

Selenium analyses of soils have not yet been accomplished to the extent that we cannot refine any correlation between the selenium in water and the geology. The occurrence of selenium appears to correlate with the more recent shales of the Plains area rather than the igneous and metamorphic rocks of the Black Hills uplift.12)

Zinc and copper remain to be summarized. All zinc concentrations in water were below 1.0 mg/l and thus were well below the threshold taste level for domestic supplies of 5.0 mg/l. Concentrations of zinc varied over two orders of magnitude from place-to-place and time-to-time. The highest concentration measured was for a sample collected near Whitewood Creek at Site 1 (0.97 mg Zn/l).

Copper was detected at all sampling sites. As was the case with zinc, concentrations varied widely from <0.005 mg Cu/l to 0.14 mg Cu/l; the latter measured for the Butte Meade Sanitary District supply which is derived from deep wells (March 1972, Site 16; value not repeated). However, concentrations were below the recommended limit for domestic uses of 1.0 mg Cu/l. Generally higher concentrations of copper were found in the Cheyenne River drainage (all upstream of the Belle Fourche River) as opposed to the Belle Fourche River drainage.

In summary, the only metal found in water in potentially detrimental concentrations was selenium. Selenium is not known to be nor was it evident that it was related to the Homestake fluid discharge but was rather related to the geology of the lower Cheyenne River Basin watershed. Arsenic was found to be present primarily in samples collected early in the program (December-March as opposed to July-October), and was in concentrations of 0.03 ± 0.01 mg As/l in two stock wells located along the Belle Fourche River (in December samples only). Mercury concentrations were assumed (assumed because of probable mercury contamination of one set of samples) to be low (0.20 µg/l), with trace amounts

12) See discussion of metals contained in Pierre Shale in previous section.

detected in only a few wells along the Belle Fourche River. Zinc and copper concentrations appeared related more to the general geohydrology of the watershed area than to the Homestake operations.

A single water sample collected from a fresh hole dug into the alluvial tailings at Site 20 contained low concentrations of mercury (?),[13] zinc, and copper, but a very high concentration (dissolved) of arsenic (4 mg/l). This may indicate that the tailings materials, once oxidized, may release arsenic more readily than fresher, dark-gray tailings (see Site 19, Whitewood Creek, where the arsenic concentration in water averaged 0.14 mg/l), since an appreciable thickness of oxidized material was encountered at Site 20.

It appears, from the data received to date, that shallow wells in the vicinity of Whitewood Creek and the Belle Fourche River are not detrimentally affected by the higher concentrations of mercury, cyanide, or arsenic contained (either presently or in the past) in these surface water channels. It may be that (1) much of the mercury and arsenic has been contained in the suspended fraction of these streams and has been filtered out prior to reaching the wells, and (2) that the river alluvium, in which the wells were completed, serves to recharge, rather than be recharged by, the surface streams and thus that dissolved metals contained in surface waters will not be detected in most wells unless the wells are pumped at a high rate.

This analysis was complicated by the lack of recent mercury and other metals data for surface waters of the area.

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13) Possible contamination, as discussed previously, may avoid any of these relatively minor conclusions regarding mercury.

SUMMARY

Alluvial sediments of a character similar to both fresh (dark gray silt) tailings as discharged from the Homestake mining and milling operations, and reddish-brown "oxidized" sands and silts probably discharged from older milling operations, were identified from aerial photographs and ground-truth data as covering in excess of 100 hectares of bank and abandoned meander channels along Whitewood Creek and the Belle Fourche River from its confluence with Whitewood Creek downstream to its confluence with the Cheyenne River. The depth of these deposits ranges from a few centimeters to perhaps three meters with the thinner surficial deposits varying in location according to the flow rate and the other deposits interbedded along the banks with sands and silts from other locales.

Concentrations of mercury in sediment samples collected from tailings-like deposits downstream of Homestake ranged from <0.1 ppm to 4.1 ppm and averaged ≤0.6 ppm Hg. Concentrations of zinc ranged from 44 ppm to 229 ppm, and averaged 81 ppm. Concentrations of copper ranged from 23 ppm to 94 ppm, and averaged 63 ppm. Concentrations of arsenic ranged from 120 ppm to 11770 ppm, and averaged 2050 ppm. Compared to samples from background locations, mercury concentrations were six-fold higher in downstream (of Homestake) sediments, zinc concentrations were constant, copper concentrations were three-fold higher, and arsenic concentrations were 200-fold higher in downstream sediments.

Ground water samples from shallow wells were assayed. No contamination of wells from surface waters downstream of the Homestake mining and milling operations could be identified with any degree of certainty. Of all analyses (Hg, Zn, Cu, As, Se, CN), only those for selenium showed detrimentally high concentrations and the locations with high concentrations were in the area of Volunteer, South Dakota, farther downstream on the Belle Fourche River, and near Wasta, South Dakota, on the Cheyenne River. While arsenic concentrations were not consistently detected (>0.01 mg/l) a few water samples did contain arsenic in concentrations (0.03 - 0.02 mg/l) approaching the 'limit' of 0.05 mg/l.

Thus, with the exception of selenium concentrations in certain wells, those wells sampled appeared, at the time of sampling, to be acceptable for their designated uses, in terms of mercury, zinc, copper, arsenic, and cyanide content. No impact upon water quality from leaching of river alluvium was identified, but a surface water sampling program was not conducted to verify this lack of impact.

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CORE LOG

SITE WC-2

SD-SED-5C (CORE) "ORIGINAL"

Collected: 18 Jul 72, 1100 hrs., Whitewood Creek nr Whitewood, S. D.
Total Core Length: 30 cm.

DESCRIPTION

0.0 - 1.3 cm.	- Dark gray silt, clayey sheen on fresh, wet face.
1.3 - 8.1 cm.	- Red-brown silt, prominent at 2.0 to 2.5 cm. and 6.8 to 7.9 cm.; similar to iron oxide staining, interbedded with similar dark gray silt.
8.1 - 25.0 cm.	- Dark gray silt, clayey sheen on fresh, wet face.
25.0 - 30.0 cm.	- Encountered pebble, 1.8 cm. x 3.8 cm., rounded quartzose sandstone, with iron staining throughout.

SD-SED-5C (CORE) "DUPLICATE" - (Replicate of SD-SED-5C)

Total Core Length: 18 cm.

0.0 - 1.3 cm.	- Dark gray silt.
1.3 - 4.3 cm.	- Red-brown quartz sand interbedded with minor gray silt. 2.3 cm. layer at top grades to 0.2 cm. stringers toward bottom.
4.3 - 5.1 cm.	- Red-brown sandy silt interbedded with dark gray silt in discontinuous lenses.
5.1 - 16.0 cm.	- Dark gray silt, clayey sheen on fresh, wet surface.
16.0 - 17.3 cm.	- Minor thin layers of brownish-red silt interbedded with dark gray silt.
17.3 - 17.8 cm.	- Dark gray silt.

CORE LOG
(CONTINUED)

SITE WC-7

SD-SED-8A

Collected: 18 Jul 72, 1515 hrs., 30 m. upstream of bridge over Whitewood Cr.
Total Depth: 107 cm.

DESCRIPTION

0 - 1.8 cm. - Dark gray silt intermixed with brownish-red sands, grading downward to gray silt.
1.8 - 7.9 cm. - Dark gray silt.
7.9 - 18.3 cm. - Dark gray sandy silt mixed with brown sand (fine sand), grading downward to silt.
18.3 - 27.3 cm. - Dark gray silt with one minor lens of reddish-brown sandy silt at about 26.7 cm.

SD-SED-8B (CORE GENERALLY DRY)

27.3 - 28.2 cm. - Dark gray sandy silt, dry.
28.2 - 32.5 cm. - Reddish-brown sand, non-cohesive.
32.5 - 37.6 cm. - Reddish-brown sand with minor dark gray silt, somewhat cohesive.
37.6 - 38.9 cm. - Gray silty sand.
38.9 - 41.9 cm. - Red-brown silty sand, quartzitic sand in 0.5 cm. bed at base.
41.9 - 46.5 cm. - Gray sandy silt.

SD-SED-8C

46.5 - 50.0 cm. - Gray to dark brown sandy silt.
50.0 - 51.6 cm. - Dark silt in 1.3 cm. sand, somewhat plastic.
51.6 - 60.4 cm. - Dark brown to gray silty sand grading to brown sand in lower 0.8 cm.
60.4 - 63.8 cm. - Gray-brown silt.
63.8 - 79.5 cm. - Brownish quartzitic sand with only minor silt.

SD-SED-8D

79.5 - 81.8 cm. - Dark gray silty sand with some brownish-red staining at irregular locations.
81.8 -101.6 cm. - Gray-brown silty sand grading slightly to brown sand in lower 7.6 cm.
101.6 -107.0 cm. - Remainder of core "lost" through compression during sample extraction.

CORE LOG
(CONTINUED)

SITE BF-4

SD-SED-10

Collected: 18 Jul 72, 1700 hrs., Belle Fourche River nr Vale, 30 m. upstream of bridge, west bank.
Total Length: 45.7 cm.

DESCRIPTION

0 - 1.3 cm.	- Gray silt and quartz sand, non-cohesive giving a dark gray appearance speckled with lighter brown.
1.3 - 2.5 cm.	- Gray silt in layer (somewhat cohesive with brown-red stringer 0.06 cm. thick at base).
2.5 - 8.4 cm.	- Silty sand, gray and brown; gray silt and quartz sand similar to 0 - 1.3 cm. interval.
8.4 -14.0 cm.	- Predominantly reddish-brown sand with minor grayish silt with minor stringers 0.02 cm. thick of reddish-brown silt.
14.0 -31.6 cm.	- Reddish-brown sand with subdued foliation delineated by light-brown quartzitic sand.
31.6 -45.7 cm.	- Core lost. On-site examination indicated that red-brown sands continued to full 46 cm. depth of hole where they gave way to gravels.

CORE LOG
(CONTINUED)

SITE BF-5

SD-SED-18A (DRYISH)

Collected: 20 Jul 72, 1400 hrs., Belle Fourche River, east bank, 17 m. downstream of bridge.
Total Depth: 168 cm. to sand; water at 90 cm.

DESCRIPTION

0 - 1.5 cm. - Dark gray sandy silt.
1.5 - 7.1 cm. - Light brown to yellowish-brown silt interbedded with minor lenses of gray silt (clayey?)
7.1 - 17.0 cm. - Red-brown sand, minor silt, numerous roots in lower half; brownish quartzitic sand at base.
17.0 - 20.0 cm. - Light brown to yellowish-brown silt grading to reddish-brown silt in lower 0.5 cm.
20.0 - 22.9 cm. - Dark gray silt, with minor black silt in lens (organics?); grades from reddish-brown silt at top of interval.
22.9 - 31.2 cm. - Red-brown sand (fine) grades in first 1 cm. to brown and quartzitic sand with large lens of dark gray silt at 29.7 ("nodule"?).

SD-SED-18B (WETTER)

31.2 - 35.6 cm. - Dark gray silt.
35.6 - 44.7 cm. - Dark gray sandy silt, grading from reddish-brown in upper 3.6 cm. to dark gray below. Some gray silt at base.
44.7 - 59.2 cm. - Dark gray silt, wet with minor reddish-brown streaks, numerous fibrous pieces (twigs?) throughout, fine varves (layers) visible at places.

SD-SED-18C (QUITE WET) - 20 cm. of 30 cm. total (10 cm. lost)

59.2 - 87.6 cm. - Dark gray silt with minor brown silt in lenses, roots (?) in upper two-thirds of core.

SD-SED-18D (WET)

87.6 - 120.6 cm. - Dark gray silt, clayey at base, minor roots (?) and black silt.

SD-SED-18E (VERY WET) - 15 cm. of top in 18F jar.

120.6 - 135.8 cm. - In jar - sample 18F.
135.8 - 153.6 cm. - Coarse brown quartzitic sand interbedded with dark gray silt in a few ill-defined beds and intermixed.
153.6 - 168.0 cm. - Remained in hole - not recoverable.

CORE LOG
(CONTINUED)

SITE BF-7

SD-SED-13C

Collected: 19 Jul 72, 1520 hrs., 6 m. upstream from bridge; 13 m. from north bank of Belle Fourche River.
Total Depth: 91.5 cm.

	DESCRIPTION
0 - 3.8 cm.	- Dark gray silt and brown sand.
3.8 - 7.1 cm.	- Dark gray silt, somewhat plastic, with minor black (organic?) silt, grading downward to brownish sand; roots in core.
7.1 - 8.6 cm.	- Brown sand interbedded with gray silt.
8.6 - 12.5 cm.	- Dark gray silt with vertical pods of black silt, the latter associated with wood-like material and about 0.8 cm. in circumference with undetermined length..
12.5 - 17.3 cm.	- Grades to brown-reddish sand through thin interbeds of gray silt and sand; numerous roots.
17.3 - 19.1 cm.	- Sand and gravel layer, semi-angular to rounded pebbles, large pebble with concentric rings of iron staining over fine-grained matrix.
19.1 - 30.5 cm.	- Dark gray silt, somewhat plastic near top, becomes silty and even sandy at base, with exception of .5 cm.-thick layer of clayey silt between 26.7 and 27.2; numerous roots.

SD-SED-13D

30.5 - 43.4 cm.	- Dark gray silt, irregularly interbedded with brownish silt and a few lenses of reddish-brown sand. Roots present and one wood twig found at 40.6 (about .5 cm. diameter X 4.6 cm. long).
43.4 - 46.7 cm.	- Sandy gravel, red and brown in color; largest pebble well-weathered to red-brown-purple colors in "fresh" exposure; pebbles rounded to sub-angular.
46.7 - 63.5 cm.	- Silt, grading from gray and brown in upper 8 cm. to gray in lower portion. Some suggestion of black silt and organic matter at ca. 53 cm; roots above 53 cm.

SD-SED-13E (last of hole in pint jar 13F

63.5 - 83.8 cm.	- Sub-angular to rounded pebbles, quartz sand, gray silt, and black silt (organic?). Large pebble is fine-grained dolomitic limestone; other, smaller ones, are quartzitic.
83.8 - 91.5 cm.	- In pint jar sample #SD-SED-13F - dark gray slimes, clayey silt, rounded pebbles, 0.6 to 1.2 cm. in diameter.

CORE LOG
(CONTINUED)

SITE BF-8

SD-SED-12G (First 12")

Collected: 19 Jul 72, 1400 hrs., Mooney Ranch, north bank.
Total Depth: 61 cm.

DESCRIPTION

0 - 1.3 cm.	- Dark gray silt with ill-defined and minor lens of brownish sand.
1.3 - 4.0 cm.	- Dark gray silt with stringers of brownish-red, fine sand and small pods (ca. 0.2 cm. thick X 1.8 cm. long) of black fine silt, possibly with some organic content.
4.0 - 9.4 cm.	- Dark gray silt, grading from red-brown sand at top and some iron-stained streaks.
9.4 - 10.2 cm.	- Major pod of black silt, fine, but possibly organic in nature, extends across 70% of 5 cm.-thick core; pod terminates in all directions within core.
10.2 - 15.7 cm.	- Dark gray silt; some hint of red-brown staining.
15.7 - 19.1 cm.	- Dark gray silt interbedded with brownish sand and minor black silt. Also isolated pieces of fibrous material which is discernible since the exterior of this material is coated with an iron oxide (?) film, red and granular in nature.
19.1 - 25.4 cm.	- Alternating dark gray silt, brown sand, and black silt in irregular stringers and lenses, grading downward to clayey silt.
25.4 - 33.0 cm.	- Dark gray clayey silt with isolated pieces of fibrous material coated with red oxidized material, grading at base to gray to brown silt.

SD-SED-12H (Second 12")

33.0 - 53.3 cm.	- Gray clayey (in portions) silt, generally massive, with infrequent reddish-brown pods containing red-brown silt; also, minor swirls of black silt toward bottom, grades to gravel at base.
53.3 - 58.4 cm.	- Gravel comprised of flat, rounded-to-sub-angular pebbles, primarily of light-colored quartz and a fine-grained, slightly calcareous, brown to purplish sand (dolomitic?), one large pebble stained in circular fashion from outside inward by iron compounds.
58.4 - 61.0 cm.	- Remainder of core "lost" in compression of samples during extraction.

CORE LOG
(CONTINUED)

SITE BF-9

SD-SED-11C - Core generally dry

Collected: 19 Jul 72, 1130 hrs., 35 m. downstream of bridge across Belle Fourche River.
Total Depth: 140.0 cm.

DESCRIPTION

0 - 2.8 cm. - Gray-brown silt in thin layers (varves) of about 0.13 cm.
2.8 - 3.6 cm. - Dark gray silt, also in thin varves.
3.6 - 7.1 cm. - Gray-brown sandy silt with reddish-brown silty sand in lens at bottom - massive.
7.1 - 7.6 cm. - Dark gray sandy silt.
7.6 - 20.3 cm. - Brown to brown-red sandy silt becoming coarser and slightly redder at base; massive.
20.3 - 24.1 cm. - Reddish-brown silt with minor lenses of dark gray silt and reddish pods of iron oxide at about 22.9 - 23.9 cm.
24.1 - 28.7 cm. - Light brown sandy silt in fine layers (varves) grading into dark brown sandy silt at base.
28.7 - 32.8 cm. - Dark brown sandy silt, grades to grayish-brown sandy silt at base.
32.8 - 33.8 cm. - Gray to brown sandy silt in thin layers (varves) alternating light brown and dark gray.

SD-SED-11D

33.8 - 35.0 cm. - Brown sandy silt.
35.0 - 35.8 cm. - Dark gray silt in thin layers.
35.8 - 38.8 cm. - Brown silty sand (quartzitic sand).
38.8 - 48.8 cm. - Grades downward to dark gray silt with 3 cm. diameter twig near base.
48.8 - 51.6 cm. - Brown silty sand with fine roots (?) with gray silt interbeds.
51.6 - 54.6 cm. - Dark gray silt with reddish-brown lenses grading downward to thin (0.02 cm.) layers of silt alternating with reddish-brown silt.
54.6 - 56.1 cm. - Light brown sandy silt.
56.1 - 58.2 cm. - Dark brown silt with irregularly-spaced layers of reddish-brown silt, minor gray silt, fine roots (?), thin varves (layers).

SD-SED-11E

58.2 - 61.2 cm. - Brown sandy silt with minor layers of gray silt and small lens of gray silt at base.
61.2 - 75.7 cm. - Interbedded brown silt, brown sandy silt, gray silt (66.8 - 68.8 cm.) massive but comprised of thin varves (layers), pieces of wood interspersed in minor quantity. Grades to wetter brown silt at base.
75.7 - 85.3 cm. - Dark gray silt grading into some reddish-brown silt at base. Wood twigs (roots?) at three locations.

SD-SED-11F

85.3 - 90.7 cm. - Dark gray clayey silt with almost bluish tint, grading downward at 88.6 cm. to silt.
90.7 - 94.2 cm. - Brownish silty sand with minor gray silt, roots near top, grades at bottom to gray silt.
94.2 - 100.3 cm. - Gray silt, minor brown sand and very minor red-brown layers or lenses. Appears to be in thin layers (varves).
100.3 - 106.9 cm. - Gray sandy silt with some red brown silt layers, grades to gray silt at base, with roots; ?(portion of core lost at top and bottom)?

SD-SED-11G (Wet portion of otherwise dry core)

106.9 - 125.2 cm. - Gray and brown silt, minor clay possibly, generally massive but tends to be comprised of globs of material and, therefore, crumbles; discontinuous red-brown sandy lens and reddish staining at 124.5 - 125.2 cm.
125.2 - 140.2 cm. - Brown and gray silt sand, massive.

APPENDIX III

PHOTOGRAPHS

SITE WC-1

Whitewood Creek, about 2.1 km. SSE of Town of Whitewood, S. D., and about 14.5 km. NE of Lead, S. D., at small road bridge - "Crook City." Photography in July 1972.

Photograph WC-1-1

Whitewood Creek, looking upstream from road bridge at Site WC-1. Sample SD-SED-4 collected from dark gray silt located as a surface covering over the poorly-sorted gravels. Note color of stream.

Photograph WC-1-2

Whitewood Creek--close-up of upstream view showing two levels of dark gray silt (lighter gray where higher and dryer). Area not identified as one containing "tailings" in November '71.

Photograph WC-1-3

Whitewood Creek, looking downstream from road bridge at Site WC-1, showing thin and recent (?) deposits of dark gray silt near channel.

SITE WC-2

Whitewood Creek, about 1.6 km. NE of Whitewood, S. D., and about 18 km. NE of Lead, S. D., at bridge carrying Whitewood Valley Road.

Photograph WC-2-1

Whitewood Creek looking upstream (SE) from road bridge showing widespread dark gray silt covering immediate flood plain and younger channel deposits. Sediment samples SD-SED-5A through C collected from left bank near edge of upper deposit.

Photograph WC-2-2

Gray silt and reddish brown sand as sampled by sediment samples SD-SED-5A through C. Collected near stream edge of upper deposit to depth of about 30 cm. Note core hole to right of pint sample. Note also gray silt layer near bottom of pit and that silt from upper layers has been smeared over the lower brown sands by shovel.

Photograph WC-2-3

Gray silt and brown sand from pit dug about 10 m. farther away from the shore (east of) sampling site showing surface layer of gray silt, sands beneath, and no silt found beneath sands.

Photograph WC-2-4

Isolated deposit of dark gray silt beyond west bank of Whitewood Creek at Site WC-2. Note that silt was deposited well away from the Creek (west bridge abutment visible in lower right).

Photograph WC-2-5

Whitewood Creek looking downstream from Whitewood Valley Road bridge near sediment sampling Site WC-2 and at Water Sampling Site 19.

SITE WC-3

Whitewood Creek, about 3.7 km. downstream NNE of Whitewood, S. D., and 19.5 km. NE of Lead, S. D., below and to west of Whitewood Valley Road.

Photograph WC-3-1

Whitewood Creek at sediment site WC-3 looking upstream from Whitewood Valley Road. Samples SD-SED-14A through F collected along near (east) bank, primarily to left side of photo.

Photograph WC-3-2

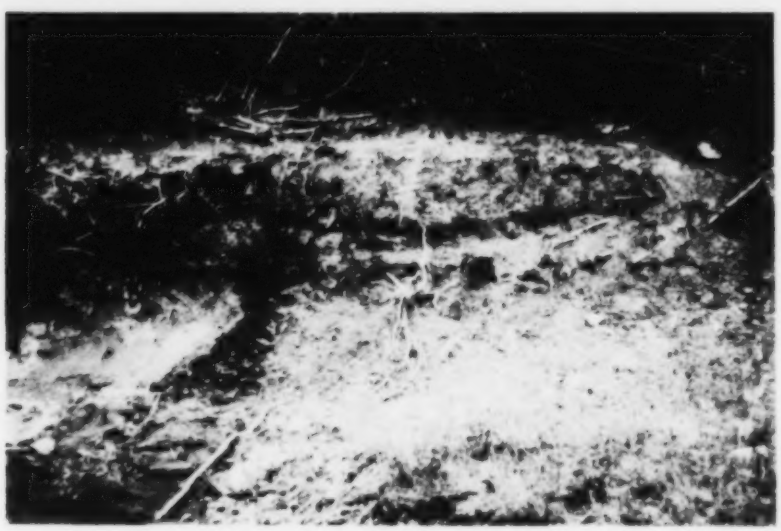
Whitewood Creek near sediment site WC-3 looking downstream. Note apparent absence of gray silt over (and in) far (west) bank. Sample of organic material (SD-SED-14A) collected from bank below trees on right.

Photograph WC-3-3

Far (west) bank of Whitewood Creek across from sediment site WC-3. Note gray silt and staining on gravels but absence of silty beds in or on the poorly sorted gravels.

Photograph WC-3-4

East bank of Whitewood Creek showing dark layers of organic-like material buried well beneath the present surface. Sample SD-SED-14A collected from dark layers at left-center of photo.



Photograph WC-3-5

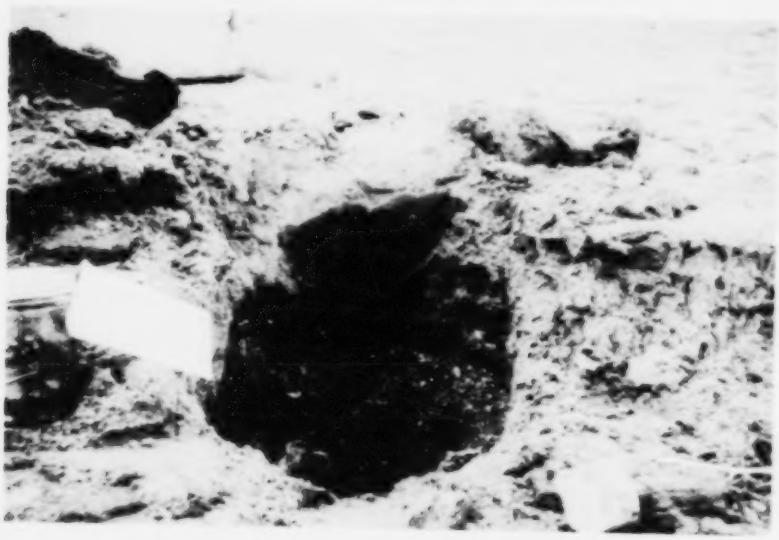
Whitewood Creek at Site WC-3 showing thin layer of dark gray silt in minor channel of Creek. Sediment sample SD-SED-14B collected from this type of deposit.

Photograph WC-3-6

Dark gray silt as thin layer over gravelly sand located on terrace/bar about 0.7 m. above stream. No silt found below gravelly sand. Sediment sample SD-SED-14C collected here.

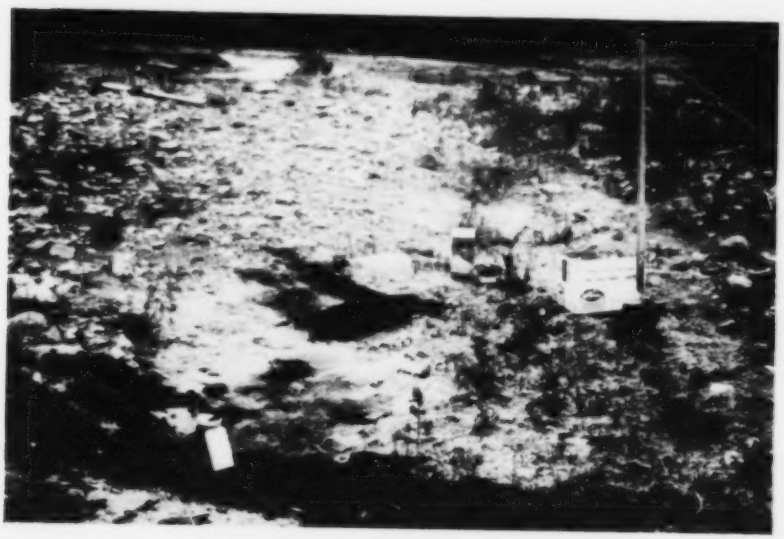
Photograph WC-3-7

East bank of Whitewood Creek at Site WC-3 showing gray silt overlying reddish-brown sands with minor gravel found sporadically over terrace about 0.6 m. above the Creek.



Photograph WC-3-8

Gravel-strewn terrace above Whitewood Creek at sediment sampling site WC-3 showing sampling locations for samples SD-SED-14D through F. Note somewhat varicolored sandy silts.



Photograph WC-3-9

Closeup of pit in foreground of Photograph WC-3-8, showing gray silt layer beneath reddish-brown sands. Silt layer sampled in SD-SED-14E as shown. Sample SD-SED-14F collected from beneath silt layer.

Photograph WC-3-10

Closeup of distant pit shown also in Photograph WC-3-8, showing some of light brown (to yellow in select strata) sand silt. Location sampled by sediment sample SD-SED-14D.

SITE WC-5

Whitewood Creek, about 10.5 km. NE of Whitewood, S. D., and 15.5 km. NE of Lead, S. D., along south bank, upstream and west of Whitewood Valley Road bridge.

Photograph WC-5-1

South side of Whitewood Creek channel showing thin, dark gray silts (note gravels showing through gray silts in left foreground) found representative of deposits in area. Sample SD-SED-6B collected here.

Photograph WC-5-2

Whitewood Creek upstream about 100 m. from Site WC-5, showing silt deposits in minor meander channel which cuts sandy gravel on far side of Creek.

Photograph WC-5-3

Freshly-eroded bank in abandoned channel of Whitewood Creek at Site WC-5, where a dark-gray silt layer was found at a depth about equal to the top of the shovel blade.

Photograph WC-5-4

Closeup of dark-gray silt layer sampled by sediment sample SD-SED-6A. Silt surrounded by brown sands. Roots were well-established.

SITE WC-6

Whitewood Creek, about 16.8 km. NE of Whitewood, S. D., and 32.3 km. NE of Lead, S. D., along east bank, in Creek channel, north of bridge carrying Whitewood Valley Road.

Photograph WC-6-1

Whitewood Creek looking downstream at thin layer of gray silt overlying gravel. Note smaller channel filled with silt at upper left of photo.

Photograph WC-6-2

View of west bank of Whitewood Creek near sediment sampling site WC-6, showing cut and slumped bank which showed no layers of gray silt.

Photograph WC-6-3

Channel of Whitewood Creek at sediment sampling site WC-6, showing thin covering of dark gray silt covering saturated gravels. Note that gravels are better sorted than was the case at locations upstream on Whitewood Creek.

SITE WC-7

Whitewood Creek, about 22 km. NE of Deadwood, S. D., 38.5 km. NE of Lead, S. D., and 2.6 km. SSW of the confluence of Whitewood Creek with the Belle Fourche River. Immediately west of bridge carrying local road.

Photograph WC-7-1

Whitewood Creek looking upstream from road bridge, showing deposit of dark gray silt on right (north) bank, behind bushes and in front of cluster of trees; about 0.3 m. above active channel. Note also the water drain from the bank at the site of the silt deposit (see Photograph WC-7-3).

Photograph WC-7-2

Terrace/bank deposit of gray tailings at Site WC-7. Sediment samples SD-SED-8A through D, a 1.1 m.-long core, collected from foreground area. Silt alternates with brown sand toward base of core.

Photograph WC-7-3

Seep of iron-rich (?) water issuing from bank into Whitewood Creek at sediment site WC-7.

SITE BF-3

Belle Fourche River, about 2.6 km. downstream of confluence with Whitewood Creek, 24 km. NE of Whitewood, S. D., and 2.7 km. NW of Vale, S. D., on north bank of river, east of State Highway 79 bridge.

Photograph BF-3-1

North bank of Belle Fourche River looking downstream from State Highway 79 bridge and gray silt along present channel; gray silt in abandoned channel on left of photo. Samples SD-SED-9A and B collected near center of photo.

Photograph BF-3-2

Closeup of gray silt covering brownish sands at Site BF-3. No silt found beneath sand. Sample SD-SED-9C collected here.

SITE BF-4

Belle Fourche River, about 1.7 km. NE of Vale, S. D., 27 km. NE of Whitewood, S. D., and 5.8 km. downstream (east) of confluence with Whitewood Creek on north bank west of road bridge.

Photograph BF-4-1

North bank of Belle Fourche River at Site BF-4. Sediment sample SD-SED-10 (core) collected in foreground from 46 cm.-thick deposit which appeared to thin to the right (north).

Photograph BF-4-2

Windblown gray silts along river bank.

SITE BF-5

Belle Fourche River, about 11.5 km. east of Vale, S. D., and 29 km. NE of Sturgis, S. D., off bridge carrying local road.

Photograph BF-5-1

Belle Fourche River, looking downstream from bridge toward sampling site for samples SD-SED-18A through F and ground water sample 20. Dark gray silt covers near bank to depth of about 1.7 m. (from core data) in series of layers.

Photograph BF-5-2

Belle Fourche River viewed upstream from Site BF-5, showing gray silt on left bank and steep, eroding bank on right.

Photograph BF-5-3

Moderately exposed photo of pit dug to water at Site BF-5, showing alternating red-brown silty sand and gray silt.

Photograph BF-5-4

Over-exposed photo of pit shown in previous photo to give clarity to water level and alternating gray silts and brownish silts at depth (~1 m.). Note that shovel blade has smeared gray silt over portions of the sands.

SITE BF-6

Belle Fourche River, about 25 km. SE of Vale, S. D., and 32 km. NE of Sturgis, S. D., by State Highway 34 bridge, at Volunteer, S. D.

Photograph BF-6-1

Sediment core sampled as SD-SED-19A and B at "upstream" location. Total depth 1.1 m. Sample SD-SED-19A collected from bottom gap in core. Sample SD-SED-19B collected from upper gap in core. Note thick gray silt strata in lower two-thirds of core.

Photograph BF-6-2

Sediment core from downstream site at BF-6, from bottom to top. Seven pint samples (SD-SED-20A through G) shown located (lettered from top to bottom). Note dry, crumbly, gray, silty clay at bottom (foreground). Total depth: about 2.2 m.

SITE BF-8

Belle Fourche River, about 43 km. SE of Volunteer, S. E., 57 km. NE of Rapid City, S. D., and 11 km. NW of Elm Springs, S. D., along north bank of river on Mooney Ranch.

Photograph BF-8-1

General area of Sediment Sample Site BF-8, looking upstream along north bank of Belle Fourche River. Samples SD-SED-12A through C collected at far right of photo. Samples SD-SED-12D through H collected at river bank near distant trees at middle left of photo.

Photograph BF-8-2

General view looking upstream along Belle Fourche River at Site BF-8. Samples SD-SED-12A through C collected to left of vehicle in distance, along bank jutting out into river. Note slumping shales along far (south) bank of river.

SITE BF-9

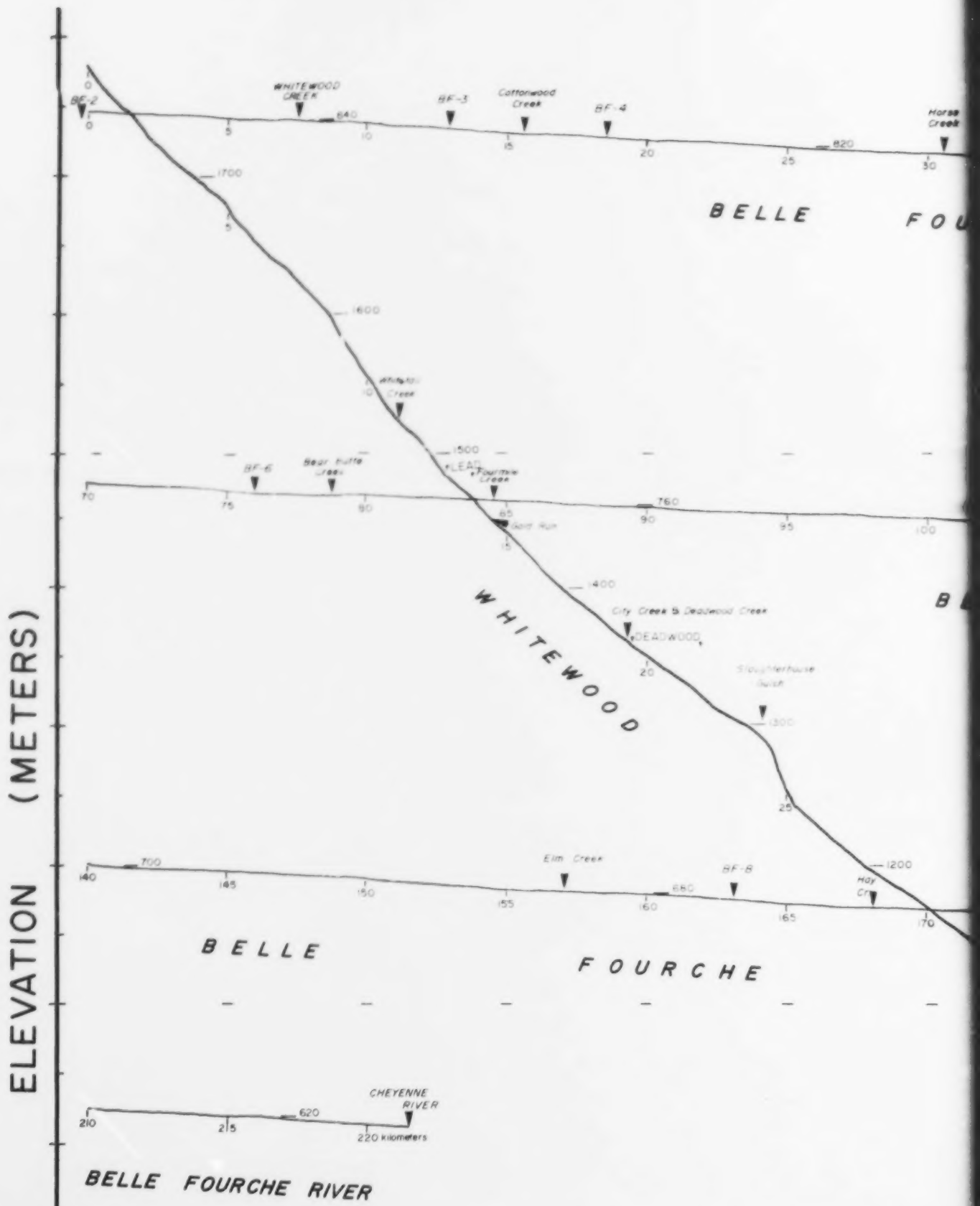
Belle Fourche River, about 49 km. SE of Volunteer, S. D., 62 km. NE of Rapid City, S. D., and 7 km. NNW of Elm Springs, S. D. Along north bank of river, upstream of bridge carrying local road between Elm Springs and Enning, S. D.

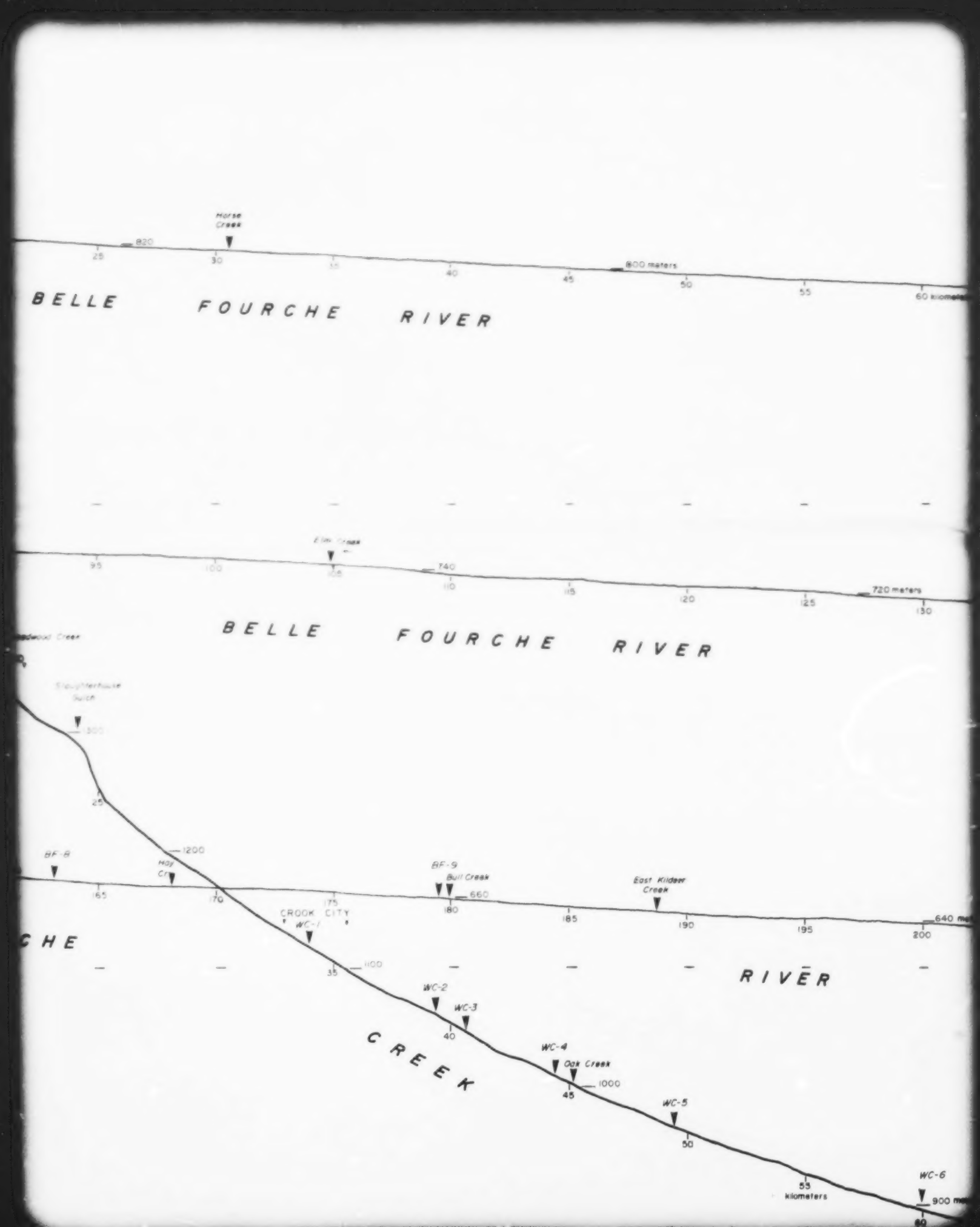
Photograph BF-9-1

Belle Fourche River in vicinity of Site BF-9. Gray silt found along bank at right. Looking downstream. Sediment site for sample SD-SED-11B located on right (south) bank.

Photograph BF-9-2

Belle Fourche River in vicinity of Site BF-9. Looking upstream with sediment sampling location for sample SD-SED-11A on bank at right (north) bank.


ELEVATION (METERS)
BF-2
WHITEWOOD CREEK
BF-3
Cottonwood Creek
BF-4
Horse Creek
BELLE
FOU
1700
1600
1500
BF-6
Bear Butte Creek
LEAD
Squirrel Creek
Gold Run
760
1400
City Creek & Deadwood Creek
DEADWOOD
WHITEWOOD
Slaughterhouse Gulch
1300
1200
700
Elm Creek
BF-8
680
Hay Cr
BELLE
FOURCHE
CHEYENNE RIVER
620
210
215
220 kilometers
BELLE FOURCHE RIVER


Horse Creek
820
25
30
35
40
45
800 meters
50
55
60 kilometers
BELLE FOURCHE RIVER
Elm Creek
95
100
105
740
110
115
120
125
720 meters
130
BELLE FOURCHE RIVER
Slaughterhouse Gulch
300
25
1200
BF-8
Hay Cr.
165
170
175
BF-9
Bull Creek
660
180
185
East Kildeer Creek
190
195
640 meters
200
CROOK CITY
WC-1
1100
35
RIVER
WC-2
WC-3
40
CREEK
WC-4
Oak Creek
1000
45
WC-5
50
55
kilometers
WC-6
900 meters

ELEVATION (METERS)
800 meters
BF-5
780
40
45
50
55
60 kilometers
65
70
VER
740
110
115
120
125
720 meters
130
Airgo Creek
BF-7
135 kilometers
140
700
URCHE RIVER
Bull Creek
660
East Kildeer Creek
185
190
195
640 meters
200
205 kilometers
210
RIVER
WC-3
WC-4
Oak Creek
1000
45
WC-5
50
55 kilometers
WC-6
900 meters
60
WC-7

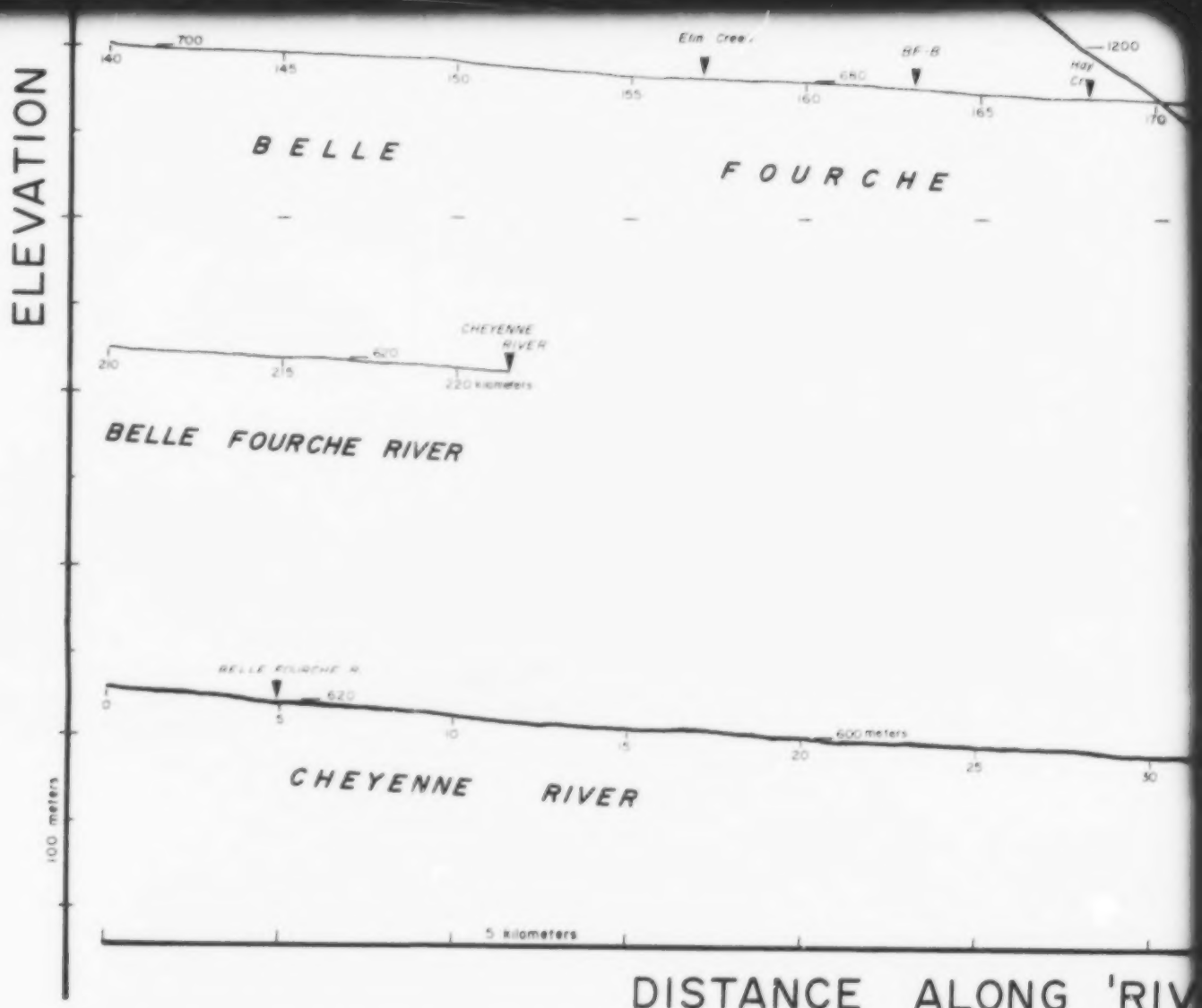
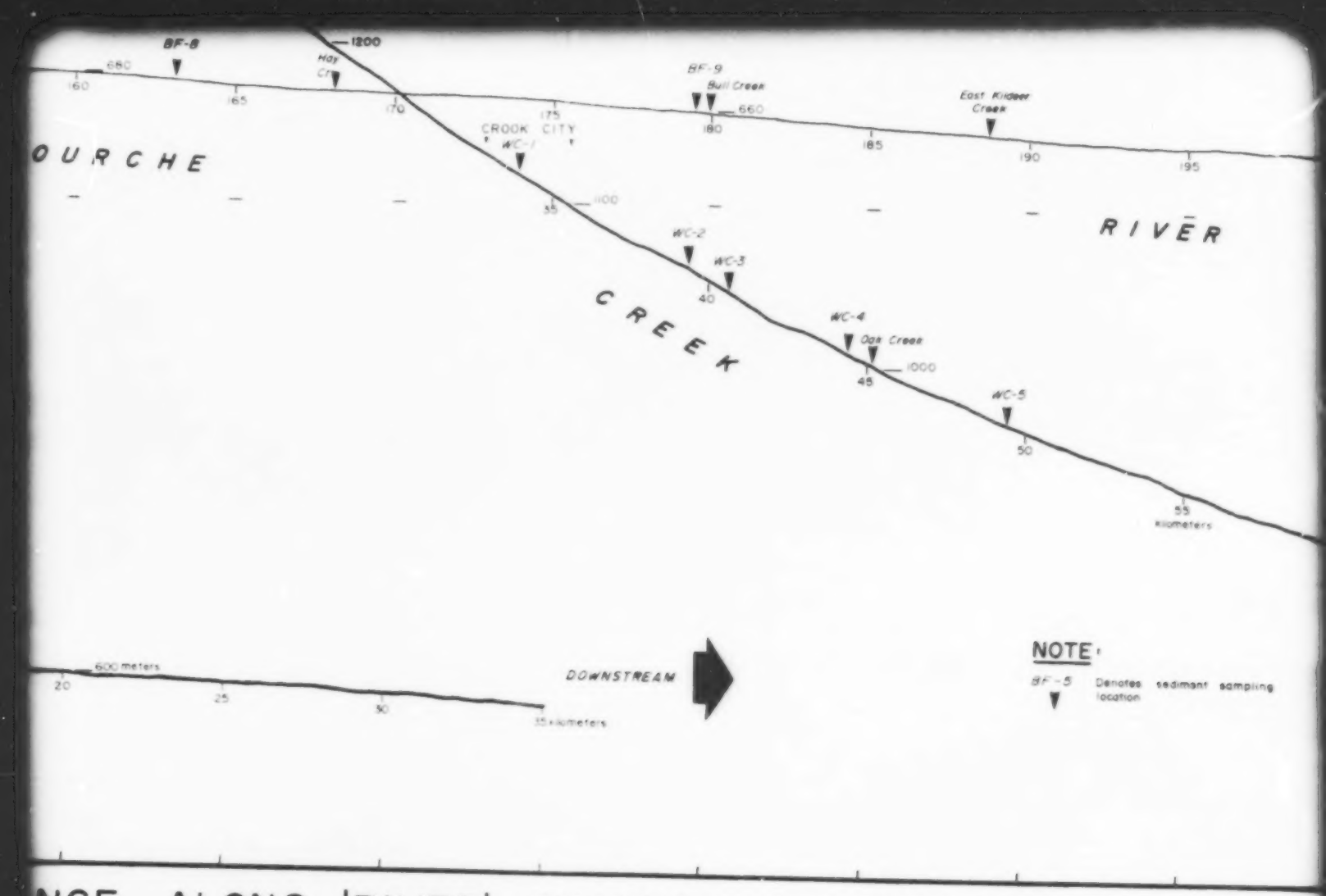
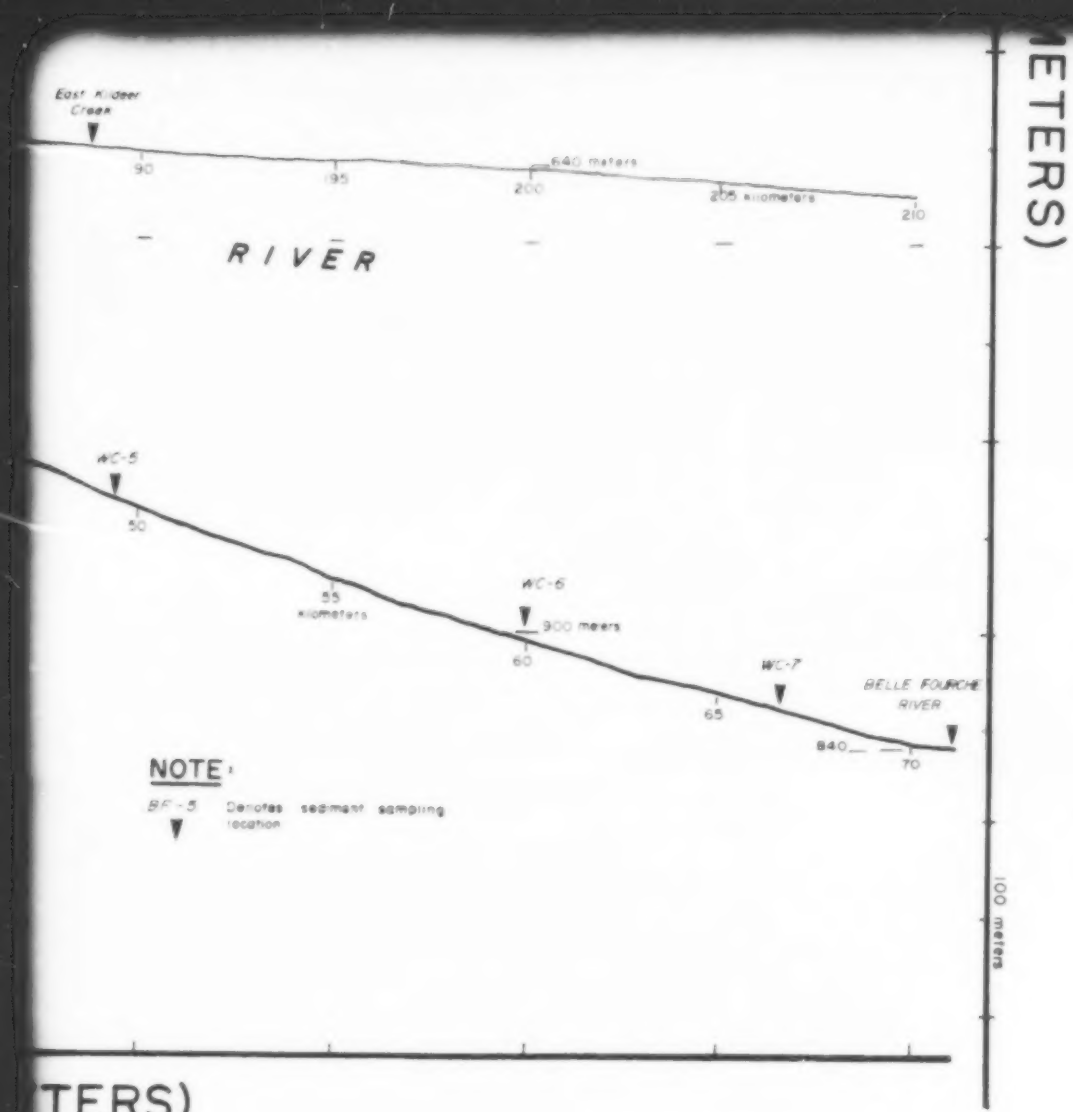


FIGURE 23
GRADIENT OF WHITEWO
RIVER , AND CHEYENNE



NCE ALONG 'RIVER' CHANNEL (KILOMETERS)

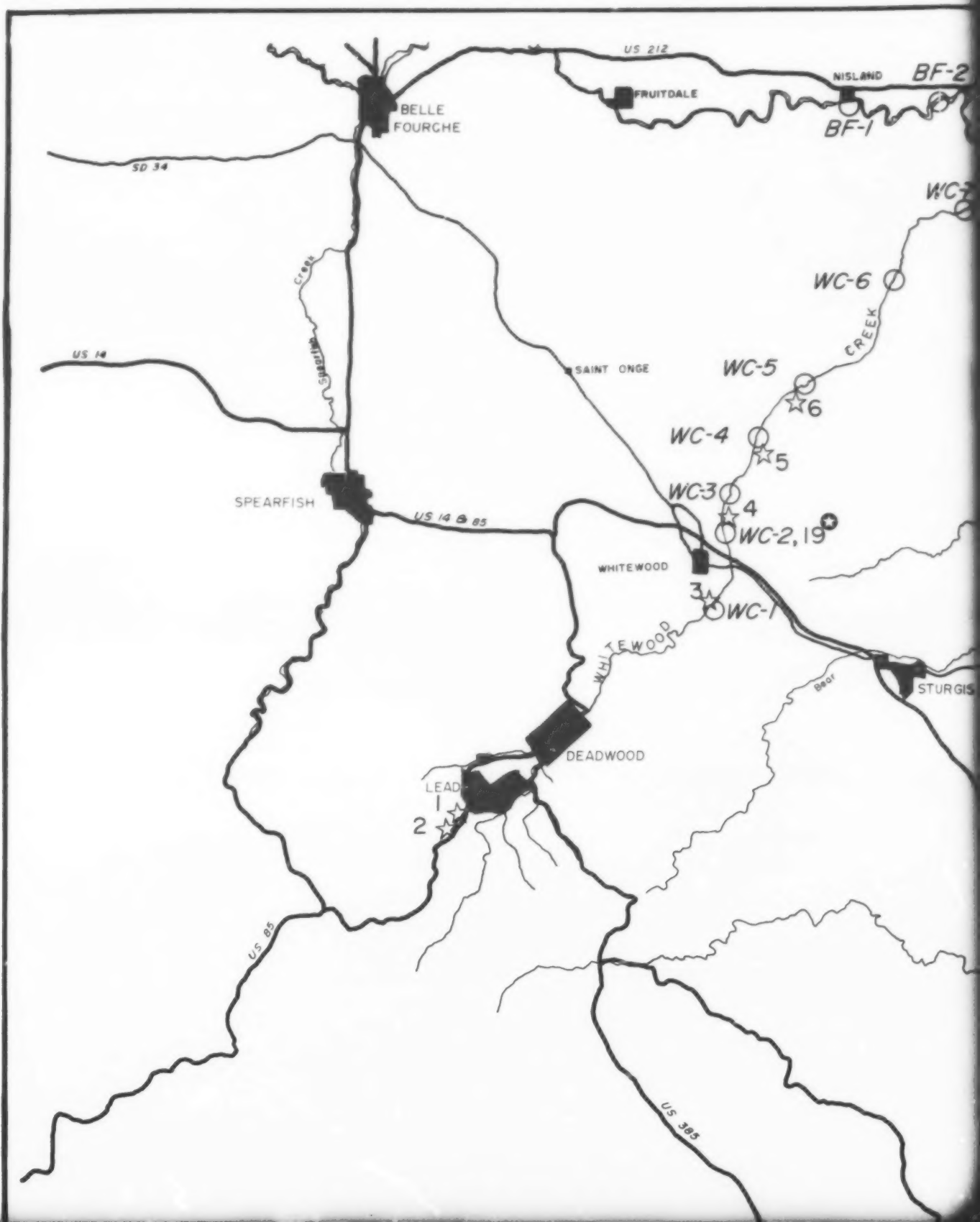
WHITEWOOD CREEK, BELLE FOUR
CHEYENNE RIVER, WESTERN SOU

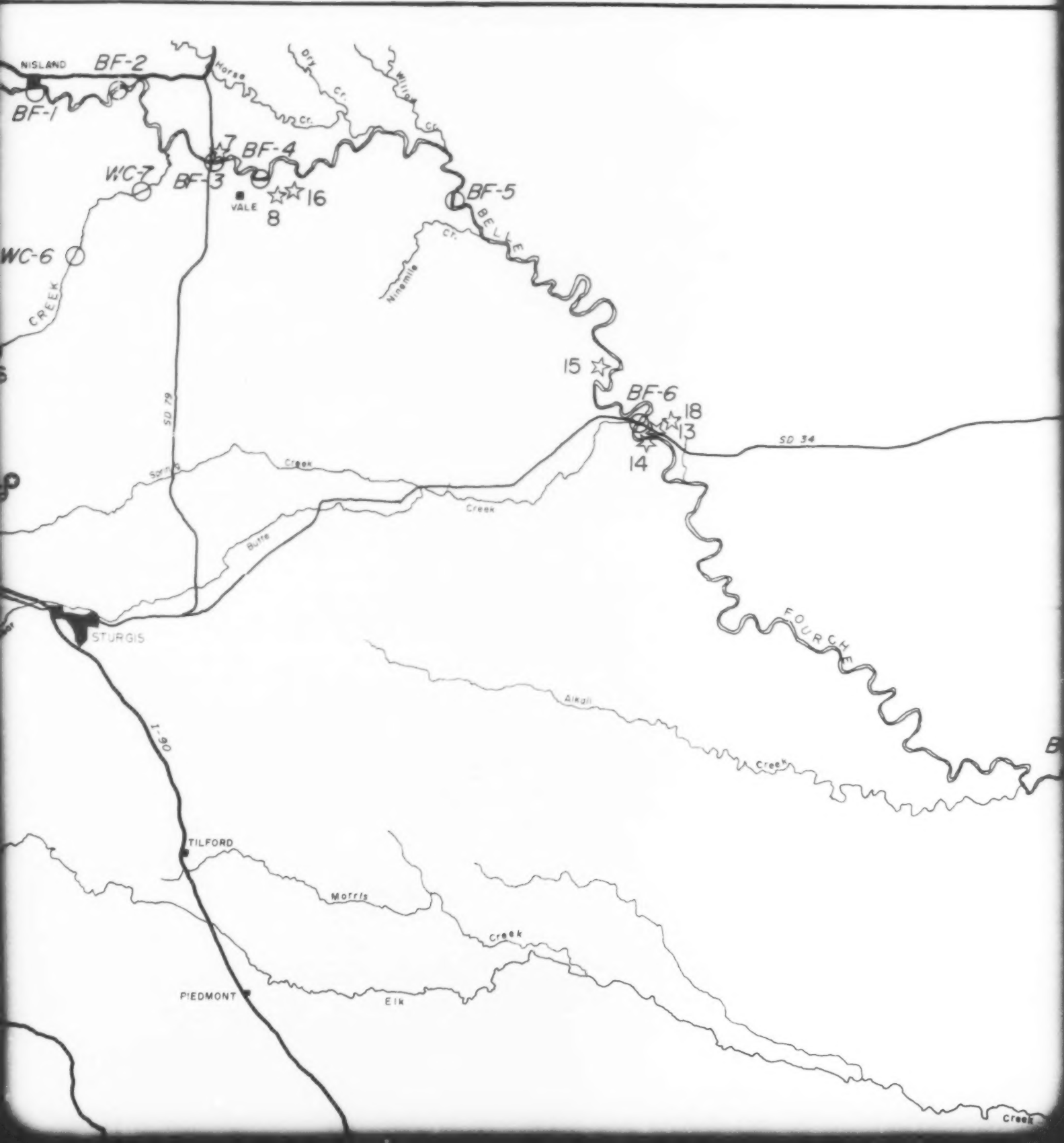


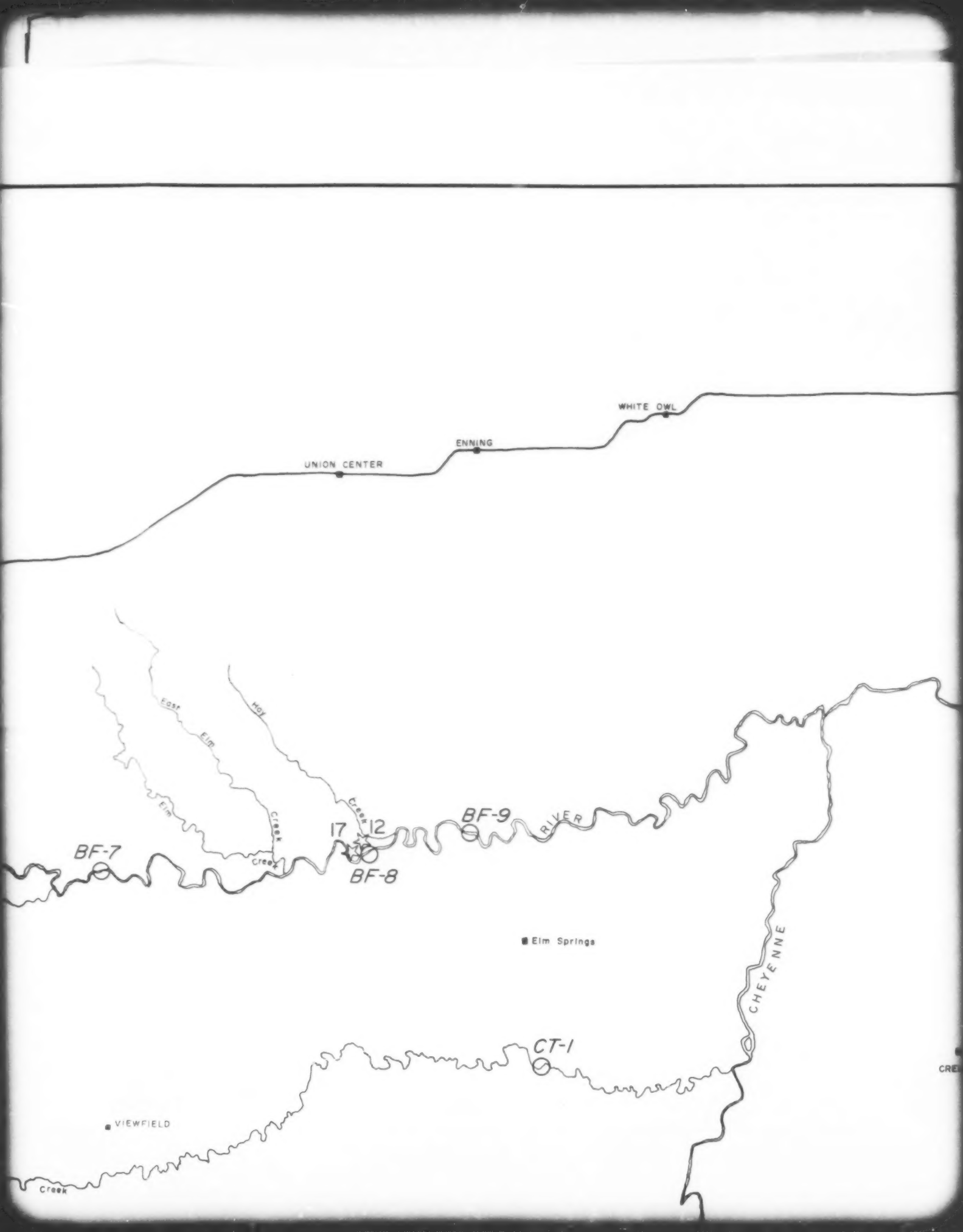
ETERS)

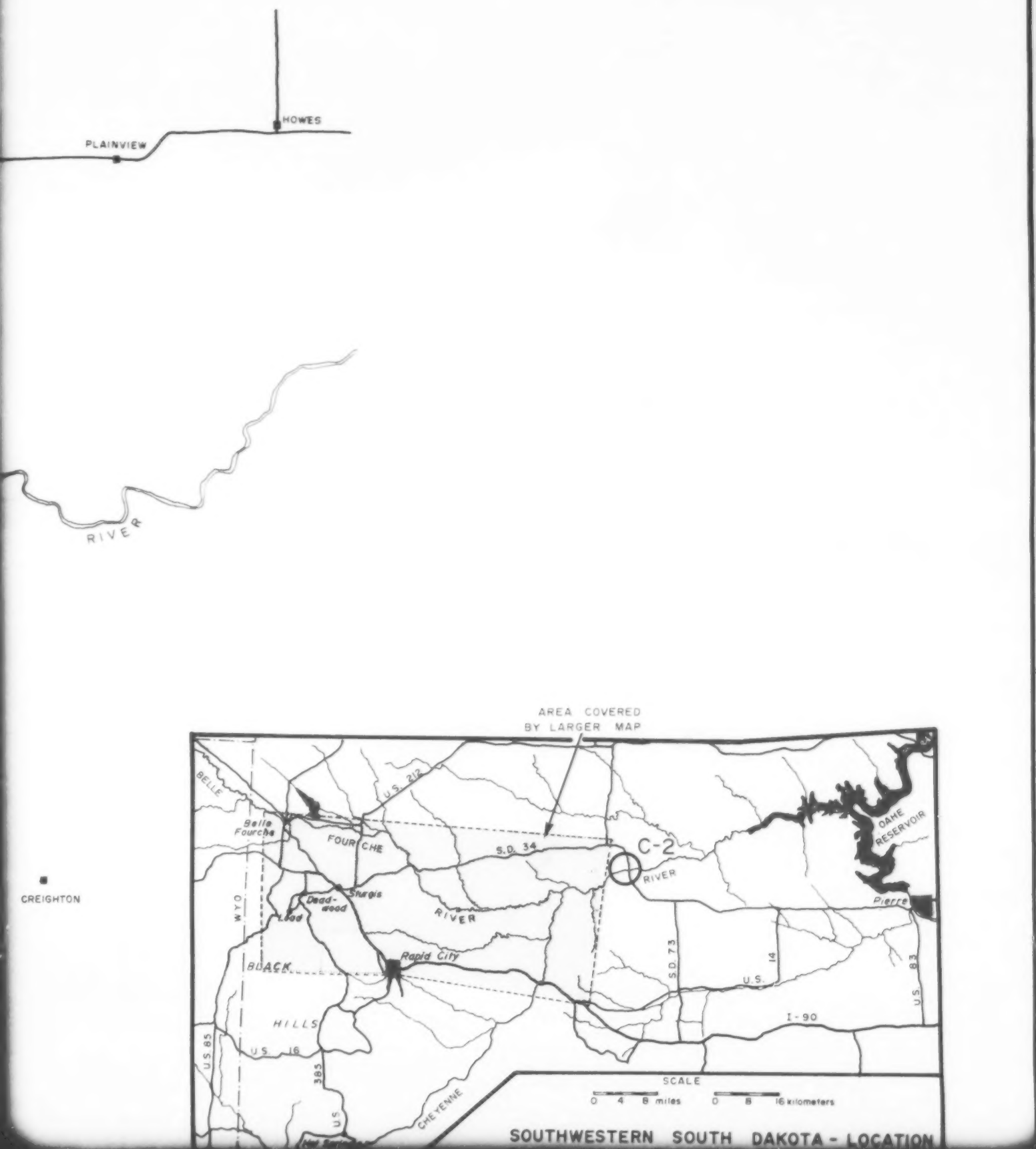
TERS)

ELLE FOURCHE
TERN SOUTH DAKOTA


US 212
NISLAND
BF-2
FRUITDALE
BF-1
BELLE
FOURCHE
SD 34
WC-7
WC-6
CREEK
Spearfish
Creek
US 14
SAINT ONGE
WC-5
6
WC-4
5
WC-3
4
SPEARFISH
US 14 & 85
WC-2, 19
WHITEWOOD
3
WC-1
WHITEWOOD
STURGIS
Bear
DEADWOOD
LEAD
1
2
US 85
US 385


NISLAND
BF-2
BF-1
Horse Cr.
Dry Cr.
Willow Cr.
BF-4
WC-7
BF-3
VALE
8
16
BF-5
BELLE
Ninemile Cr.
WC-6
CREEK
SD 79
15
BF-6
18
13
14
SD 34
Creek
Butte
STURGIS
FOURCHE
Alkali
Creek
I-90
TILFORD
Morris
Creek
PIEDMONT
Elk
Creek


WHITE OWL
ENNING
UNION CENTER
East
Elm
Creek
Hay
Creek
Elm
Creek
Creek
17
12
BF-7
BF-8
BF-9
RIVER
Elm Springs
CHEYENNE
CT-1
VIEWFIELD
Creek


HOWES
PLAINVIEW
RIVER
CREIGHTON
AREA COVERED
BY LARGER MAP
BELLE
U.S. 212
Belle Fourche
FOURCHE
S.D. 34
C-2
OAHE RESERVOIR
RIVER
Pierre
WYO
Dead-wood
Lead
Sturgis
RIVER
BLACK
HILLS
Rapid City
S.D. 73
14
U.S.
U.S. 83
I-90
U.S. 85
U.S. 16
385
U.S.
CHEYENNE
SCALE
0 4 8 miles
0 8 16 kilometers
SOUTHWESTERN SOUTH DAKOTA - LOCATION

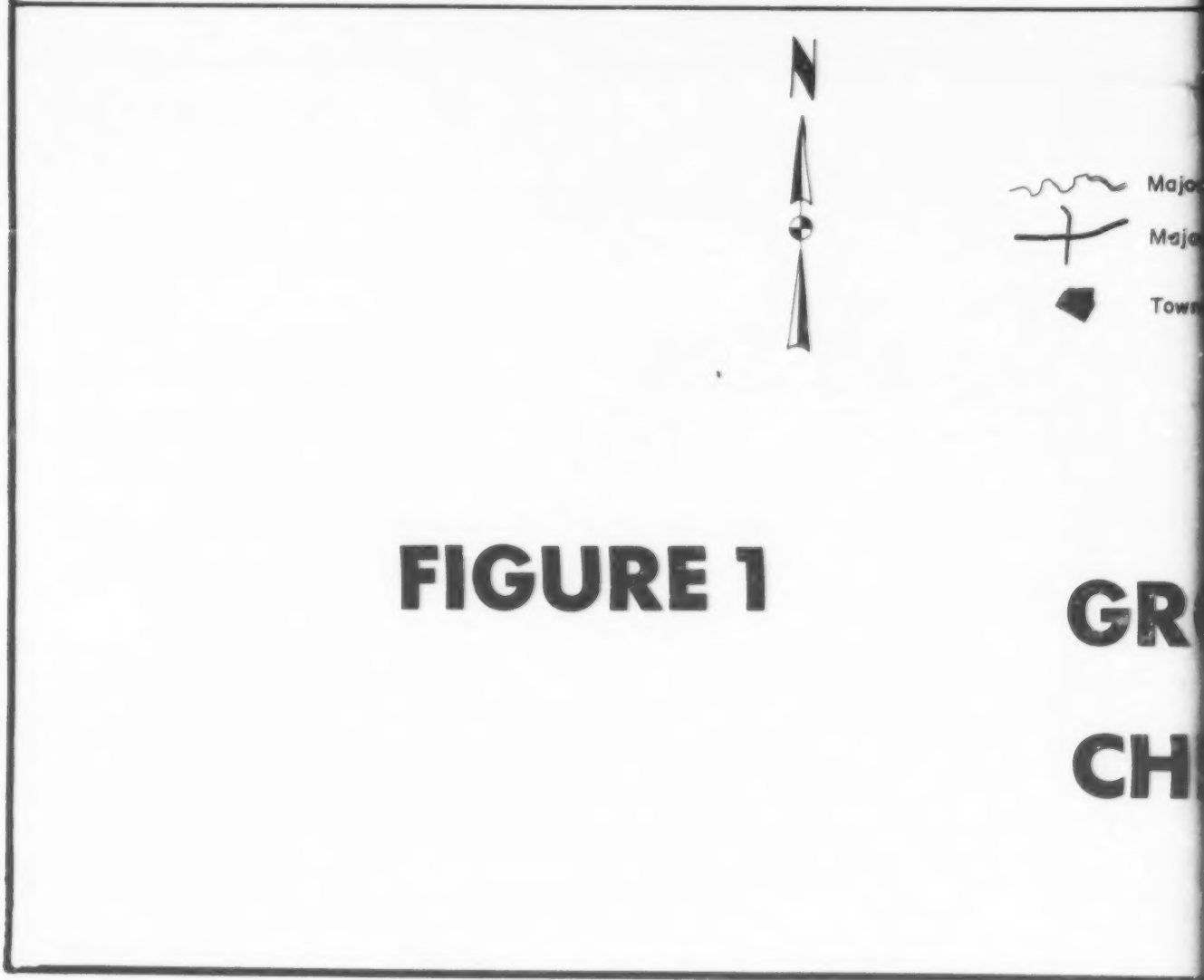
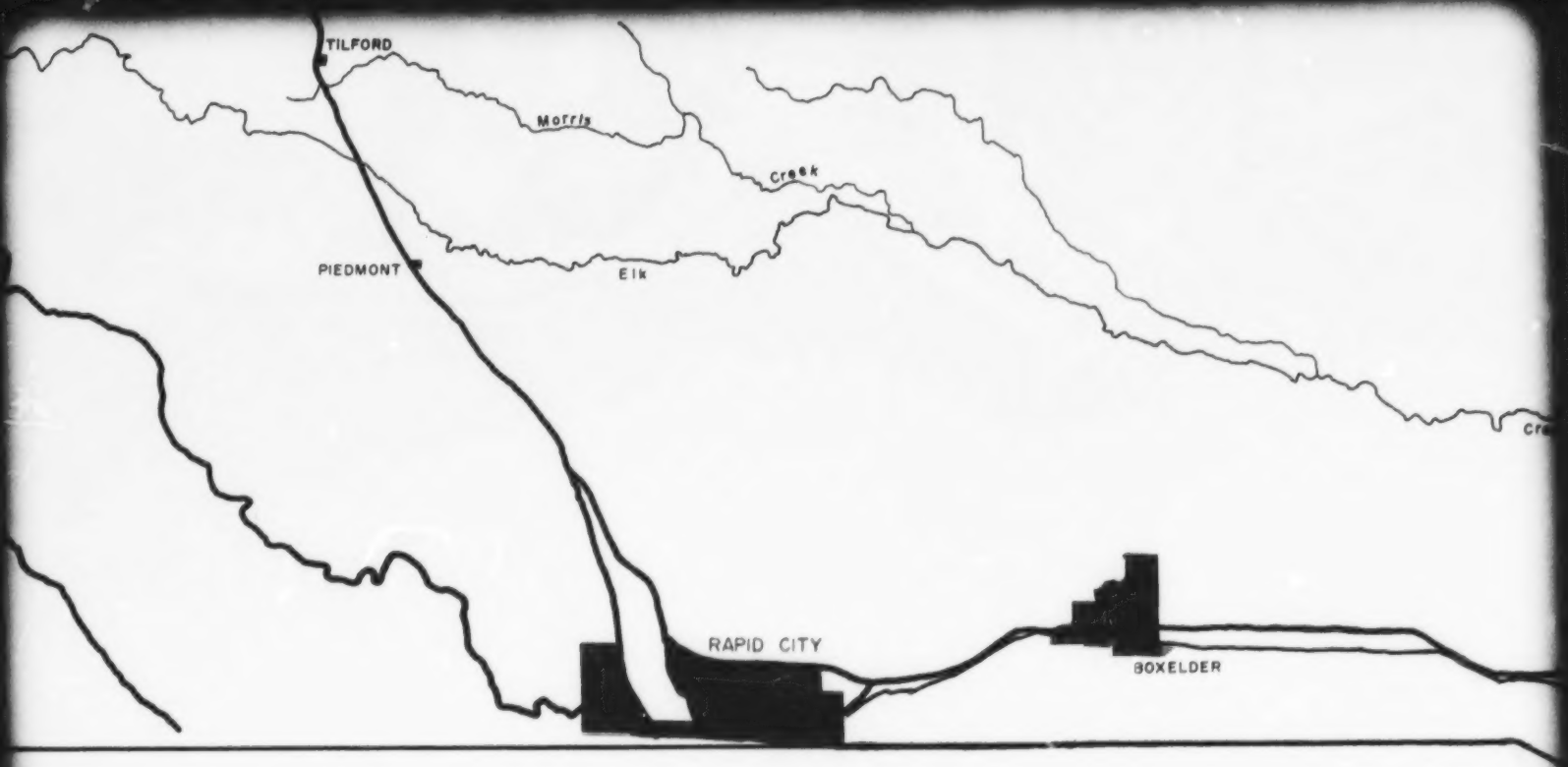


FIGURE 1

GR

CH



EXPLANATION

- Major drainage system
- Major highways
- Towns and Cities
- WC-6 ○ Sediment sampling site
- 14 ☆ Water sampling site
- 19 ✪ Surface water

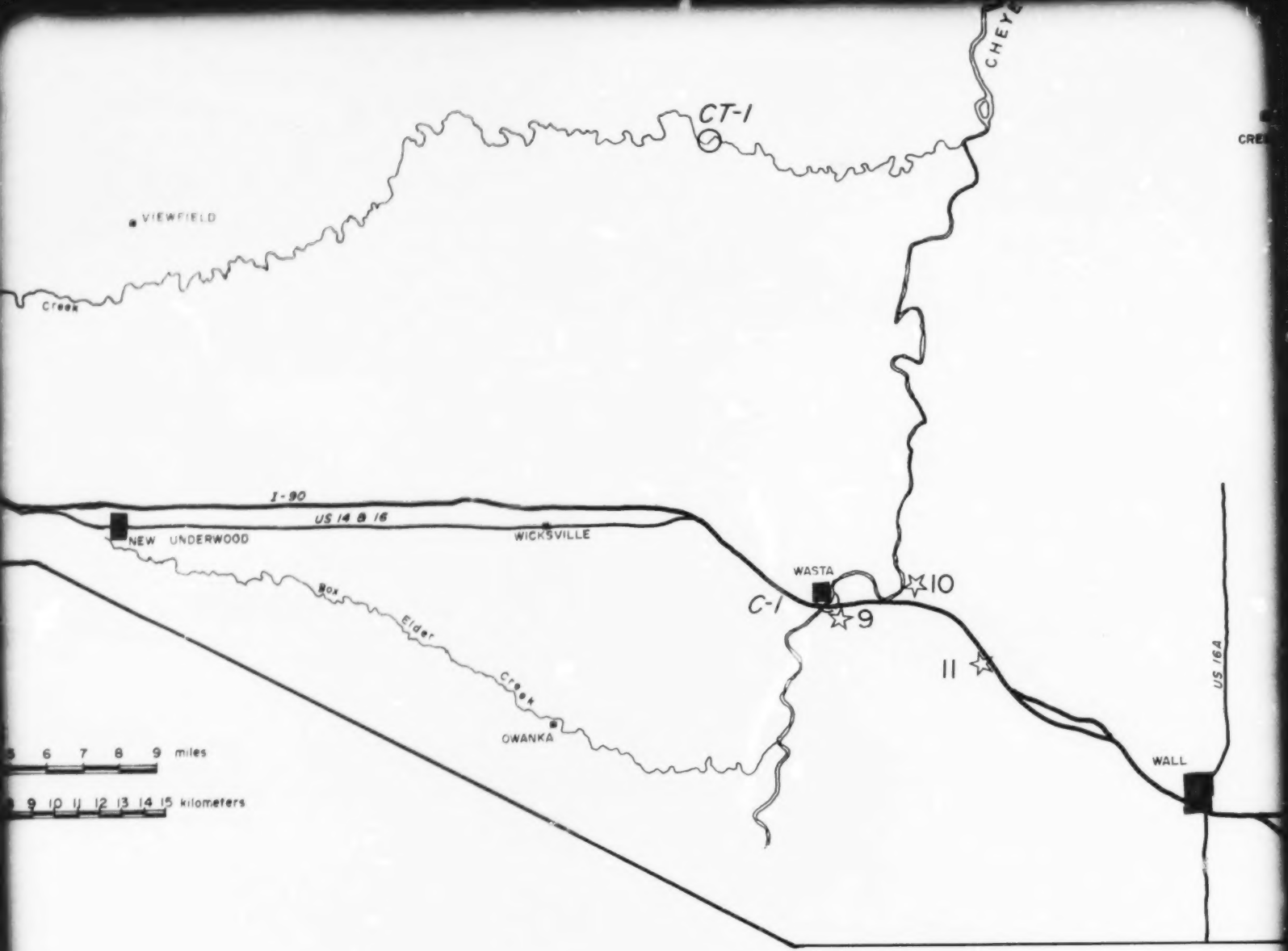
SCALE

1 0 1 2 3 4 5 6

1 0 1 2 3 4 5 6 7 8 9 10

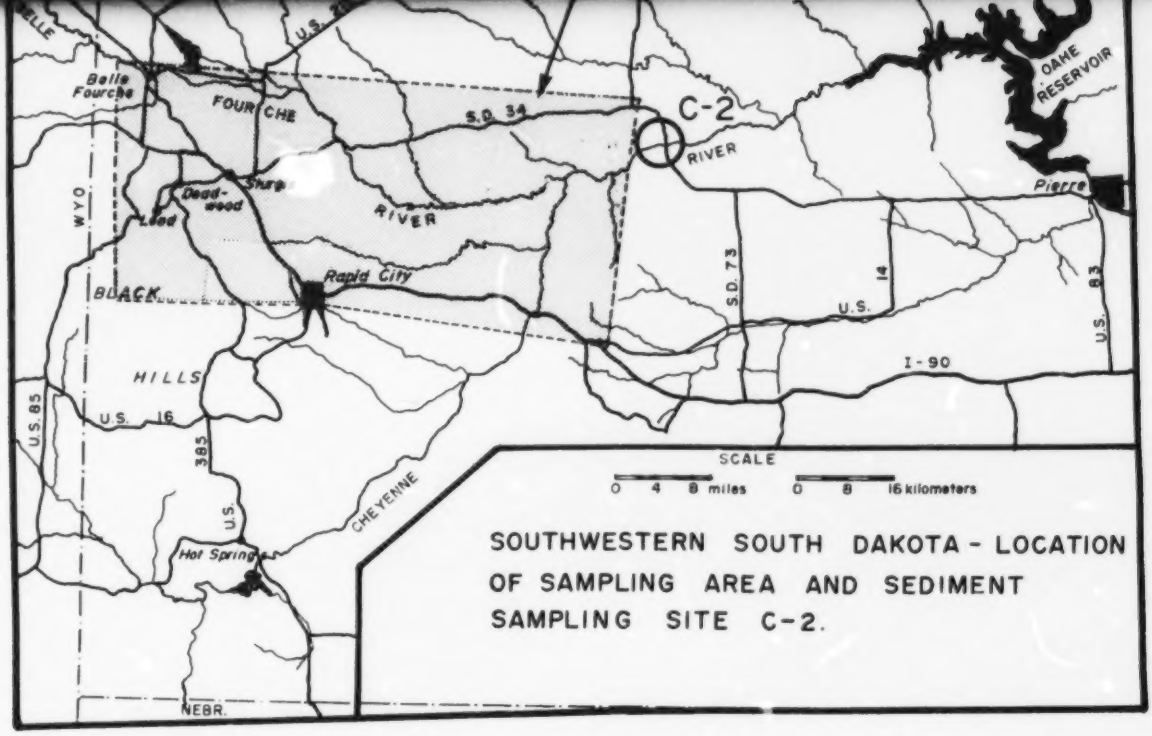
GROUND WATER AND SEDIMENT

CHEYENNE RIVERS WHITEWO



NT SAMPLING LOCATIONS BELLE

OOD CREEK WESTERN SOUTH D



SOUTHWESTERN SOUTH DAKOTA - LOCATION OF SAMPLING AREA AND SEDIMENT SAMPLING SITE C-2.

CREIGHTON

US 164

I-90

LE FOURCHE AND

H DAKOTA